REPORT DOCUMENTATION PAGE

OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave blank)

2. REPORT DATE
June 7, 1995

3. REPORT TYPE AND DATES COVERED

4. TITLE AND SUBTITLE
Effect of Exercise and Exercise Combine with Electrical Stimulation on Diastasis Recti: A Single Subject Design

5. FUNDING NUMBERS

6. AUTHOR(S)
Kerry Lyn Sitler

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
AFIT Students Attending:
The University of Oklahoma (HSC)

8. PERFORMING ORGANIZATION REPORT NUMBER
AFIT/CI/CIA
95-047

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
DEPARTMENT OF THE AIR FORCE
AFIT/CI
2950 P STREET, BDLG 125
WRIGHT-PATTERSON AFB OH 45433-7765

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

DTIC
SELECTE
JUL 1 3 1995
S D
G

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for Public Release IAW AFR 190-1
Distribution Unlimited
BRIAN D. GAUTHIER, MSgt, USAF
Chief Administration

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

DTIC QUALITY INSPECTED 5

14. SUBJECT TERMS

15. NUMBER OF PAGES
64

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT

18. SECURITY CLASSIFICATION OF THIS PAGE

19. SECURITY CLASSIFICATION OF ABSTRACT

20. LIMITATION OF ABSTRACT

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18

GRADUATE COLLEGE—THE UNIVERSITY OF OKLAHOMA

Report on ~~*Comprehensive*~~ *Final* *Examination*

(Cancel one)

June 7, 1995 19__

Date of Examination

To the Dean of the Graduate College:

We, the undersigned, as a committee, have examined Kerry Lyn Sitler

__________, a candidate for the degree of Master of Science

and report the following results:

SATISFACTORY

~~UNSATISFACTORY~~

(Cancel one)

Mark R. Anderson Chair

Irene R. Mc Ewen

JeanLea Spitz

Billy L. Elam

I dissent from the foregoing report for the following reasons:

This report, duly signed by all members of the examining committee reporting the candidate's performance whether it be satisfactory or unsatisfactory, is due in the Graduate Dean's Office 72 hours following the examination.

THE UNIVERSITY OF OKLAHOMA HEALTH SCIENCES CENTER

GRADUATE COLLEGE

EFFECTS OF EXERCISE AND EXERCISE COMBINED WITH ELECTRICAL STIMULATION ON A DIASTASIS RECTI: A SINGLE SUBJECT DESIGN

Accesion For		
NTIS CRA&I	☒	
DTIC TAB	☐	
Unannounced	☐	
Justification		
By		
Distribution /		
Availability Codes		
Dist	Avail and / or Special	
A-1		

A THESIS

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

degree of

Master of Science

BY

KERRY L. SITLER, MAJOR, USAF, BSC

Oklahoma City, Oklahoma

1995

EFFECTS OF EXERCISE AND EXERCISE COMBINED WITH ELECTRICAL STIMULATION ON A DIASTASIS RECTI: A SINGLE SUBJECT DESIGN

APPROVED BY

Mark A. Anderson

Mark A. Anderson, PhD, PT, ATC, Chair

Irene R. McEwen

Irene R. McEwen, PhD, PT, PCS

Jean Lea Spitz

Jean Lea Spitz, MPH, RDMS, FSDMS

Billy D. Elam

Billy D. Elam, MPH, PT

THESIS COMMITTEE

ACKNOWLEDGMENTS

I want to take this opportunity to gratefully acknowledge the professional guidance I have received for the past two years from the graduate and undergraduate faculty of the Department of Physical Therapy of the University of Oklahoma Health Sciences Center. I especially want to thank my thesis committee members. Dr. Anderson and Dr. McEwen opened new doors into the world of research for me, they allowed me the flexibility to expand my new knowledge, and demonstrated extraordinary patience and understanding throughout the arduous task of rewriting and editing this thesis. My appreciation also goes to Professor Elam, a dear colleague and confidant, who provided me with positive support throughout my graduate studies. I also want to thank Professor Spitz for sharing her expertise and kind editing on the diagnostic ultrasound sections of this thesis.

Kind appreciation is also extended to the 72 Medical Group Obstetrical staff, to Sandy Baker from the Radiology Department, and to the Department of Physical Therapy staff for their assistance and use of their facilities for this research project.

I would also like to thank both the United States Air Force and the

Women's Health Section of the American Physical Therapy Association for their financial support in the form of a full scholarship to complete this master's degree and a grant towards my research efforts.

I am particularly indebted to recent University of Oklahoma graduates Captain Gary Sherwood, M.S., P.T. and Major Ernie Liddle, M.S., P.T. for paving the road and for setting the example for all incoming Air Force graduate students in this program.

A special thank you is also in order for all the wonderful "moms" who participated in this research study. Without their dedication and time, this study would not have been possible. In addition, heart felt appreciation is extended to Kelly Baker, M.P.H. for her statistical assistance and to Pam Weted for her computer keyboard magic.

Finally, I would like to say thank you to my husband Gary. He was my pillar of strength and support in my moments of self-doubt, in times of intense challenges and through my failures and my triumphs. His unconditional love made these two years much more bearable.

I am truly indebted to each and all of you for helping me achieve this goal. God bless you for your patience, your support, and for your time.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EFFECTS OF EXERCISE AND EXERCISE COMBINED WITH ELECTRICAL STIMULATION ON DIASTASIS RECTI: A SINGLE SUBJECT DESIGN

CHAPTER I

INTRODUCTION

In the physical therapy management of the obstetrical patient, the opportunity to effectively evaluate and treat associated musculoskeletal dysfunction is gaining popularity. A common musculoskeletal condition found during and after pregnancy is a diastasis recti abdominis.[1-4] The term diastasis simply means "separation of."[5] Many researchers believe that this separation occurs secondary to the softening of connective tissues related to the hormonal releases of progesterone and relaxin, and to the prolonged stress of a progressive weight gain, and subsequent weakness of the abdominal muscles associated with pregnancy.[6-8] Other sources have speculated that a diastasis recti may be directly related to a large birth weight baby or to multiple births, to the mother's fitness level before and during her pregnancy, to a previous history of connective tissue disease, or to belonging to a particular race.[2,3,4,9] Diastasis recti can also be found in young children, in patients with chronic obstructive pulmonary disease, or following abdominal surgery, with obesity and malnutrition, or with chronic constipation. [2,9,10]

Because diastasis recti is usually not painful, it often goes unnoticed and untreated. This condition, however, may lead to persistent weakness of the abdominal musculature and predispose the patient to low back pain.[11-14] Both Kendall et al[11] and Porterfield et al[13] suggest that anterior abdominal muscle weakness can lead to postural changes and excessive mobility at the lumbo-pelvic region, therefore predisposing an individual to both lumbosacral and sacroiliac strains and sprains. Visceral functions such as, exhalation, coughing, urinating, defecating, singing, vomiting, and delivering a baby may also be adversely affected.[4,5,10]

Few studies have identified how to measure for a diastasis recti.[10,15,16] Bursch[16] found poor interrater reliability among four physical therapists when using the finger width measurement procedure. This measurement method was first described by Webster[15] and requires investigators to place their fingers horizontal to the linea alba while the patient performs a partial curlup. To date, no research literature has been found that demonstrated objective and reliable measurements for a diastasis recti.

Many soft tissue dysfunctions are now being confirmed with diagnostic ultrasound, computed tomography (CT)scans, and with magnetic resonance imaging (MRI).[17-20] Merritt et al[17] cited that diagnostic ultrasound is safe, inexpensive to use and maintain, and provides good to excellent three dimensional images. In contrast, CT scans use ionizing radiation and are expensive to use and MRIs, though found to be safe and highly effective in providing clear and concise information, are also extremely expensive to use and maintain.[17] Kaplan et al[18] found that the rectus abdominis muscle, which is encased in easily visualized fascia, is an excellent structure for ultrasound imaging. More recent studies showed diagnostic ultrasound to be reliable and valid in the assessment of both superficial and deep soft tissue structures.[21-23] From these finding, it appears that diagnostic ultrasound may be an objective, reliable, and cost effective method of measurement for a diastasis recti.

Another gap in the literature existed regarding the efficacy of diastasis recti correction exercises. However, Noble's[3] corrective exercise has been promoted in numerous obstetrical related texts and articles pertaining to pre- and postnatal exercises.[3,16,24-31] Other articles on the treatment of diastasis recti ranged from "doing nothing" to the surgical correction of this condition.[9,32-34] In fact, Elbaz et al[9] contends that a patient with a diastasis recti measuring more than 4.0 centimeters is a candidate for surgical correction. Many rehabilitation protocols now employ electrical stimulation combined with exercises following post injury or surgery to the extremities. Experimental studies performed by Delitto et al[35] and Eriksson et al[36] on the effects of electrical stimulation on the quadriceps muscles following knee surgery have shown successful outcomes in regaining strength. Recent studies on the effects of electrical stimulation for muscle reeducation of abdominal muscles have also been conducted with varying results. Though using different electrical stimulation units and highly variable parameters, most of these studies demonstrated an increase in abdominal strength with the use of electrical stimulation.[37-42]

The purposes of this study are to determine effective physical therapy treatment(s) for reducing a diastasis recti and to determine if diagnostic ultrasound can be a reliable method for objectively measuring the midline separation associated with a diastasis recti.

Research Questions

Specifically, this study will address the following questions:

I. Is Noble's corrective exercise alone effective in reducing and/or correcting a diastasis recti in patients between six weeks and two years postpartum?

II. Is electrical stimulation combined with Noble's corrective exercise effective in reducing and/or correcting a diastasis recti in patient between six weeks and two years postpartum?

III. Is diagnostic ultrasound a reliable method for measuring diastasis recti?

CHAPTER II

LITERATURE REVIEW

In the following literature review diastasis recti abdominis (which will be referred to as diastasis recti) will be defined, the functional anatomy of the anterolateral abdominal wall musculature reviewed, and the incidence and etiology of diastasis recti as related to pregnancy reported. Lastly, the evaluation of this condition will be described, along with previous and current physical therapy and medical interventions.

Definition

The term diastasis simply means "separation of."[5] In this condition the rectus abdominis muscles separate in the midline at the linea alba which is a well recognized complication of pregnancy.[1-4] This separation occurs frequently during pregnancy due to increased weight gain, weakened abdominal muscles, and softening of connective tissue related to hormonal releases of estrogen, progesterone, and relaxin.[6-8] According to Bursch[16], the widening and thinning of the midline fascia usually occurs during the second trimester of pregnancy and immediately following delivery. The abnormality seen clinically is a gapping of the linea alba that permits a protuberance of abdominal viscera to occur with increased intraabdominal pressure. In 1941, Iason[2] described three degrees of separation, which included:

> a) Incomplete separation. The fibers of the linea alba are merely attenuated or separated, but not completely severed, thus leaving the linea alba greatly widened. b) Incomplete, complete separation. There is a complete separation and division of the linea alba extending from the symphysis pubis to the umbilicus: the remaining fibers are normal above the umbilicus, or only partly separated, and c) Complete separation. This is a condition in which the fibers of the linea alba are completely separated from the xiphoid cartilage to the symphysis pubis. Only skin and peritoneum are left in this defensive line as coverage for the abdominal viscera.

Iason failed to provide any numerical measurements to his degrees of separation; however, in 1990, Ranney[10] provided three quantitative categories of diastasis recti during surgical corrections of umbilical hernias and/or during a hysterectomy procedure. These consisted of: "a mild diastasis with an observed separation of more than one and less than three centimeters between the medial fibers of the recti muscles; a moderate diastasis measuring three to five centimeters; and a severe diastasis measuring five or more centimeters."[10] Ponka[4] reported that some controversy exists among physicians regarding the significance and management of a diastasis recti and its effects on abdominal function.

Functional Anatomy

The four anterolateral abdominal muscles composed of the paired transversus abdominis, internal oblique, external oblique, and rectus abdominis muscles are all significant to diastasis recti. The fascial contributions of the transversus abdominis, the internal oblique, and the external oblique muscles form the rectus sheath, which totally encase the rectus abdominis muscles. The linea alba is formed as the paired aponeuroses of the transversus abdominis, internal oblique and external oblique muscles fuse in the midline between the two rectus abdominis muscles.[5,43,44] Figure 1 displays these four anterolateral abdominal wall muscles.[44] Table 1 outlines their origins, insertions, fiber directions, and muscle actions.

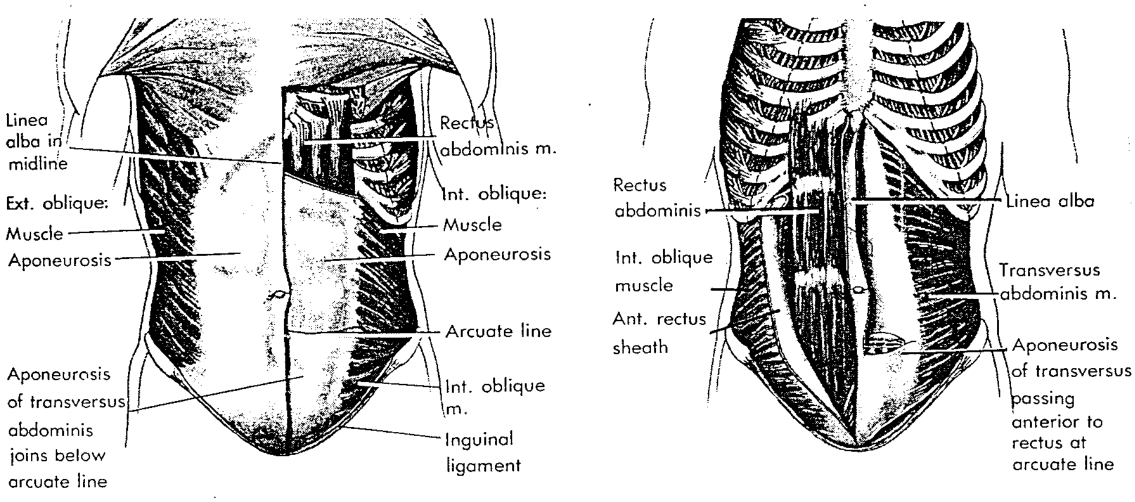


Figure 1. Anterior Abdominal Wall Muscles. (Printed with permission from Gardner WD, et al: Structure of the Human Body, 2nd ed, Philadelphia, WB Saunders Ca., 1973).

Table 1.Origins, insertions, fiber direction, and actions of the anterolateral abdominal wall muscles. (Adapted with permission from Kendall FP, et al: Muscles Testing and Function. 4th edition. Baltimore, Md: Williams & Wilkins; 1993).

Transversus Abdominis

ORIGIN: Inner surfaces of the 6th-12th costal cartilages, blending with the diaphragm; thoracolumbar fascia; anterior three-fourths of the internal lip of the iliac crest; and lateral one-third of the inguinal ligament.
INSERTION: Linea alba by means of a broad aponeurosis, pubic crest, and pecten pubis.
FIBER DIRECTION: Horizontally or transversely.
ACTION: Acts like a girdle to flatten the abdominal wall and compresses the abdominal viscera and the upper portion helps to decrease the intersternal angle of the ribs in expiration. Also helps stabilize the linea alba and is the second most important muscle in the delivery of a baby.[45]

External Oblique

ORIGIN: Anterior fibers attach to the external surfaces of 5th-8th ribs blending with the serratus anterior muscle. Lateral fibers attach to the external surface of 9th rib blending with serratus anterior and external surfaces of 10th-12th ribs blending with the latissimus dorsi muscle.
INSERTION: Anteriorly into the fibrous anterior rectus sheath and terminating in the linea alba. Laterally to the anterior superior iliac spine and pubic tubercle and into the external lip of the anterior one half of the iliac crest.
FIBER DIRECTION: Both anterior and lateral fibers are directed obliquely in a downward and medial direction.
ACTION: Acting bilaterally, the anterior fibers flex the vertebral column approximating the thorax and pelvis anteriorly, supports and compresses the abdominal viscera, depresses the thorax, and assists in respiration. Acting unilaterally with the anterior fibers of the internal oblique on the contralateral side, the anterior fibers of the external oblique rotate the trunk, bringing the thorax forward (when the pelvis is fixed), or the pelvis backward (when the thorax is fixed). Acting unilaterally with the lateral fibers of the internal oblique on the ipsilateral side, the lateral fibers sidebend the trunk, approximating the thorax and iliac crest. The lateral fibers also act in concert with the lateral fibers of the internal oblique on the contralateral side.

Internal Oblique

ORIGIN: The lower and upper anterior fibers originate on the lateral two-thirds of the inguinal ligament, the anterior superior iliac spine, and on one-third of the intermediate line of the iliac crest. The lateral fibers originate on the middle one-third of intermediate line of the iliac crest and the thoracolumbar fascia.
INSERTION: The lower and upper anterior fibers insert with the transversus abdominis into the crest of the pubis, medial part of the pectineal line, and into the linea alba by means of the rectus sheath (aponeurosis). The lateral fibers insert onto the borders of the 10th-12th ribs and linea alba.
FIBER DIRECTION: The lower anterior fibers extend transversely across the lower abdomen. Both the upper anterior and lateral fibers extend obliquely upward and medially.
ACTION: The lower anterior fibers compress and support the lower abdominal viscera in concert with the transversus abdominis. The actions of the upper anterior and lateral fibers are described in the above external oblique section.

Rectus Abdominis

ORIGIN: Pubic crest and pubic symphysis.
INSERTION: Costal cartilages of 5th-7th ribs and xiphoid process of the sternum.
FIBER DIRECTION: Vertically downward.
ACTION: Flexes the trunk by approximating the thorax and pelvis anteriorly. With the thorax fixed, flexes the pelvis on the trunk. With a fixed pelvis, flexes the thorax on the pelvis.

Noble[3] compared the abdominal musculature to a well-crafted girdle with a four-way support system. This support system is comprised of the overlapping internal and external obliques that provide a criss-cross configuration found in most foundation garments. In addition, the transversus abdominis provides a horizontal waistband and the rectus abdominis provides an upright and centrally located panel.[3] This elaborate muscular support system is responsible for working in concert with the posterior trunk muscles to help maintain an erect standing posture by providing stability to the cervico-lumbar spine as well as to assist with trunk mobility. In addition, the abdominal muscles help maintain a tube-like shape to the trunk by compressing the abdominal viscera and are essential in increasing intrabdominal pressure during visceral functions, such as, exhalation, coughing, urinating, defecating, singing, vomiting, and in parturition.[4,5,11] In the case of diastasis recti, a weakened abdomen can affect any and possibly all of these functions.

Etiology and Incidence

Diastasis recti can be found in young children, in patients with chronic obstructive pulmonary disease, obesity, malnutrition, or with chronic constipation. It can also be found in patients following abdominal surgery or congenitally in people with increased elasticity of connective tissues and muscles.[2,4,9] Pregnancy is the most common etiologic factor associated with diastasis recti.[1,2,4,9,15] Boissonnault et al[24] found the incidence of diastasis recti during the second and third trimesters of pregnancy to range between 27 to 66 percent with a 36 percent incidence rate five to seven weeks postpartum. This cross-sectional research design tested 71 primiparous women placed in one of five groups, based on placement within the childbearing year.[24] Interestingly, the incidence of pregnancy-related low back pain is reported to be between 48-56 percent.[46-48] In a descriptive study, Bursch[16] found a sixty-two percent postpartum incidence rate in 40 subjects tested four days after a vaginal delivery. Finally, in a case study of 1738 women who underwent an abdominal hysterectomy, Ranney[10] surgically observed an incidence rate of 39 percent.

Some controversy was also found in the literature as to the location of the diastasis. Earlier literature reported most separations between the rectus abdominis muscles being found below the umbilicus following pregnancy.[1,2,15] More recent studies found the widest area of separation at the umbilicus in 53 percent of pre and postnatal patients studied. In this same study, the widest separation in 11 percent of the patients occurred below the umbilicus and 36 percent were found above the umbilicus.[24] These more recent findings are consistent with the anatomical make-up of the aponeurosis of the abdominal wall. This is best illustrated in the cross-section of the rectus abdominis and its sheath in Figure 2.

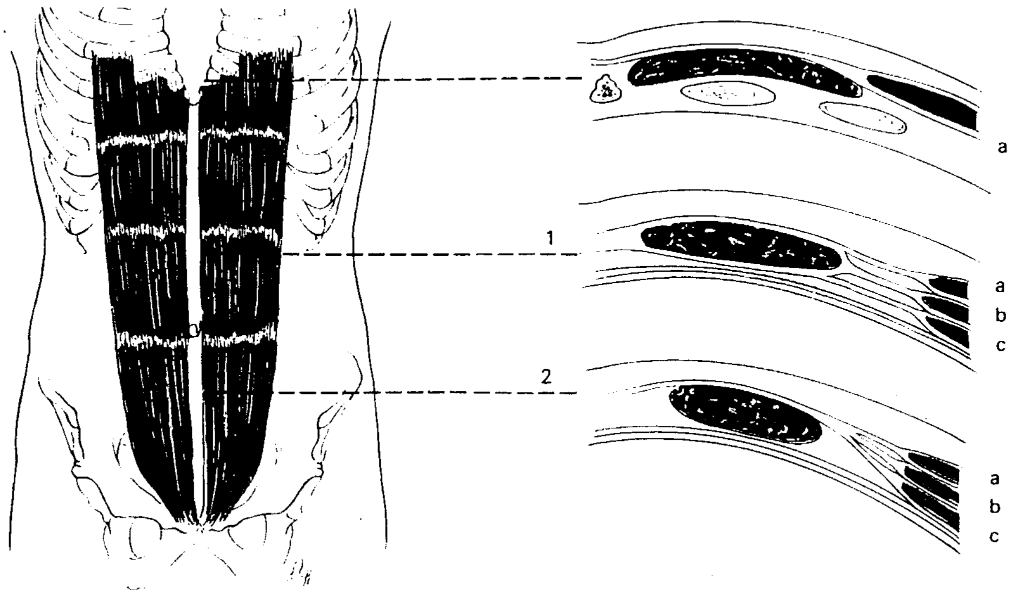


Figure 2. Cross section of the rectus abdominis muscle and its sheath. 1) Above the arcuate line the aponeurosis of the internal oblique (b) divides. Its anterior lamina fuses with the aponeurosis of the external oblique (a) to form the ventral layer of the rectus sheath. Its posterior lamina fuses with the aponeurosis of the transversus abdominis (c) to form the dorsal layer of the rectus sheath. 2) Below the arcuate line the aponeurosis of all three muscles (a-c) fuse to form the ventral layer of the rectus sheath. (Printed with permission from Kendall FP, et al: Muscles Testing and Function. 4th edition. Baltimore, Md: Williams & Wilkins; 1993.)

Above the arcuate line, the aponeurosis of the external oblique joins the anterior layers of the rectus sheath, whereas the internal oblique aponeurosis splits to form anterior and posterior layers of the sheath. Finally, the transversus abdominis aponeurosis joins the posterior layer. However, below the arcuate line, the three aponeuroses join and fuse anteriorly, thereby providing more support to the lower abdomen.[5,11,43,44]

When muscles are maintained in a lengthened position beyond their neutral physiologic position for a prolonged period of time, a stretch weakness can occur.[11,49,50] Kotarinos[45] contends that a stretch weakness occurs to the abdominal muscles during pregnancy secondary to the expanding gravid uterus taking up residence in the abdomen. During pregnancy, the uterus slowly grows out of the pelvic region during the fourth month of pregnancy and continues to take over an ample portion of the abdomen until delivery.[45] When coupling the prolonged stresses of a progressive weight gain with increases in hormone production associated with pregnancy, it should not come as a surprise that a diastasis recti is found so frequently during and after pregnancy.

Both Kendall[11] and Porterfield et al[13] advocate that anterior abdominal muscle weakness can lead to postural changes and excessive mobility at the lumbo-pelvic region, therefore predisposing an individual to both lumbosacral and sacroiliac strains and sprains. Kendall[11] further claims that even several years after onset, partial to full return to strength in these overstretched and weakened muscles can be achieved.

Evaluation

Diastasis recti may vary in severity from one person to the next. Ponka[4] refers to diastasis as "an anatomic variant that borders on a pathological state". Normal variations of one to two centimeters of separation may occur along the entire length of the linea alba.[5] Noble[3] contends that a diastasis recti measuring greater than two centimeters should be addressed by corrective exercises.

Webster[15] described the procedure for evaluating a diastasis recti by having the patient lie supine with both knees flexed and feet supported on a flat surface. The patient is then asked to perform a partial curl up, that is, raise her head and shoulders slightly off the surface while reaching towards her knees. Therapists can then measure for a diastasis recti by placing their fingers horizontally across the linea alba and determine how many fingers fit into the space between the medial borders of the two rectus abdominis muscles. Kotarinos[31] felt that performing the head raise alone until a minimal contraction was felt in the abdomen was a more sensitive measure. Electromyographic studies of the rectus abdominis support this revised method for measuring a diastasis recti.[51-54] Bursch[16] recommended that measurements be taken at the umbilicus, 4.5 centimeters above, and 4.5 centimeters below the umbilicus to ensure that a sizable portion of the linea alba was checked. In this nonrandomized study, she also found poor interrater reliability (0.40 to 0.69) among the four physical therapists using the finger-width method of measuring for postpartum diastasis recti in 40 subjects. She speculated that the inherent differences in therapist finger width as well as the subjective impression of pressure to the area contributed to this unreliable method of measuring a diastasis recti.[16] Figure 3 demonstrates how to evaluate a diastasis recti.

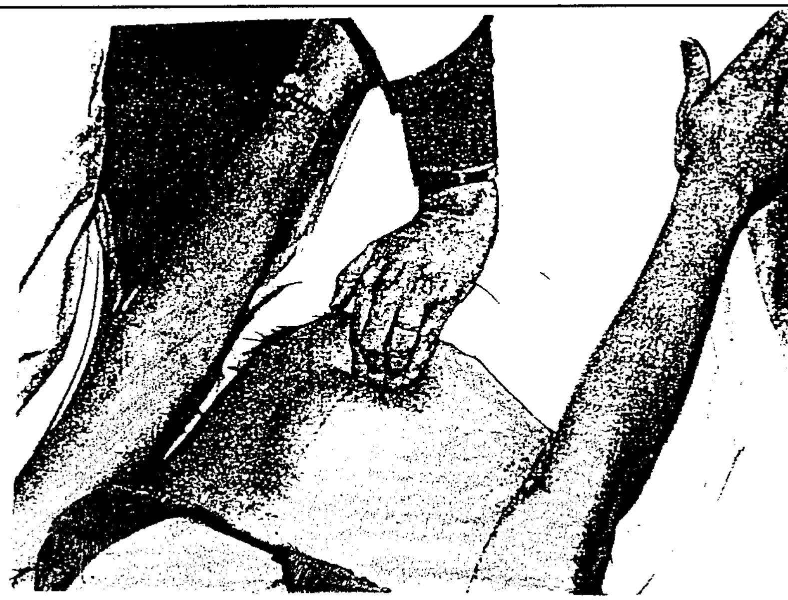
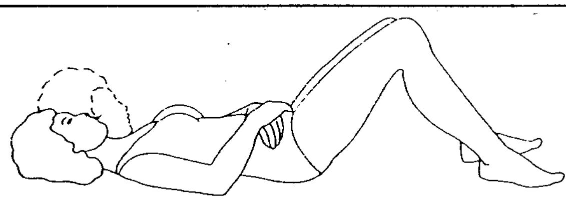


Figure 3. Finger-width technique for measuring a diastasis recti abdominis.

To date, no literature has been found that demonstrate objective and reliable measurements for a diastasis recti. Many soft tissue dysfunctions are now being confirmed with diagnostic ultrasound, computed tomography (CT) scans, and magnetic resonance imaging (MRI).[17-20] In a recent descriptive study, Merritt et al[17] reported that diagnostic ultrasound is safe, inexpensive to use and maintain, and provides good to excellent 3 dimensional images. In contrast, CT scans use ionizing radiation and are expensive. MRIs, though found to be safe and highly effective in providing clear and concise information, are also extremely expensive to use and maintain.[17] In another descriptive article, Kaplan et al[18] found that the rectus abdominis muscle is an excellent structure for ultrasound imaging secondary to being encased in fascia. More recent studies showed diagnostic ultrasound to be reliable and valid in the assessment of both superficial and deep soft tissue structures.[21-23] In a nonrandomized study of 35 subjects, Bellisari and her associates[21] compared the reliability of skinfold measurements to B-mode ultrasound measurements of subcutaneous fat. They found excellent coefficients of reliability ranging from 0.91 to 0.98 for the ultrasound measurements. In a quasi-experimental study assessing the reproducibility of ultrasound in the measurement of pancreatic size in 10 subjects, DiGiandomenico et al[22] found satisfactory reliability (0.84) with the use of ultrasound imaging. Finally, in a three year case study with 8530 subjects, Graf[23] used ultrasound imaging to detect developmental abnormalities at the hip in infants from birth to six weeks of life. He concluded that ultrasound was both safe and an effective tool in assessing newborn hips. From these findings, it appears that diagnostic ultrasound may be an objective, reliable, and cost effective method of measurement for a diastasis recti.

Treatment

Noble[3] set the standard in the rehabilitation of a diastasis recti with the development of a specific muscle reeducation exercise to reduce and/or correct diastasis recti. This particular exercise has been promoted in numerous obstetrical related texts and articles pertaining to pre and postnatal exercises.[3,16,24-31] However, the efficacy of this exercise has not been determined. In this exercise, the patient is positioned supine with both knees bent and feet flat on a firm surface. The patient then places her crossed hands over her abdomen to support and pull the rectus abdominis muscles towards the midline. Finally, the patient is asked to slowly raise her head until a slight contraction is felt in the abdomen, holding for 3-5 seconds and repeating the exercise up to 50 times a day. Figure 4 demonstrates Noble's corrective exercise for a diastasis recti.



Diastasis recti correction exercise. *Lying supine with her knees bent, the woman places her crossed hands on her recti muscles. As she exhales, she raises her head without raising her shoulders, simultaneously using her crossed hands to draw the recti muscles toward the midline. Then she lies back while inhaling and relaxes her abdomen. (Raising the head activates only the recti muscles. Other motions, such as raising the shoulders, activate additional abdominal muscles, creating an imbalance that further separates the recti muscles.)*

Figure 4. Diastasis recti correction exercise. (Modified with permission from Noble E: Essential Exercises for the Childbearing Year. 3rd edition. Boston, MA: Houghton Mifflin Co; 1988.)

Electromyographic studies support this particular exercise, that is, the head raise, in isolating the rectus abdominis muscle.[51-54]

Kotarinos[31] recommended a modification to the crossed hands method consisting of wrapping a bed sheet around the patient's midsection and then having the patient gently pull the two ends of the sheet taut across the body. This technique acts much like an abdominal binder and may in fact provide more support than the hands method. Previous and more recent literature also advocate the use of abdominal binders for abdominal hernias and midline separations.[2,55] Thornton[55] found that an abdominal corset employed during the second stage of labor was invaluable in substituting for the weakened and overstretched transversus abdominis muscles. In this case study, Thornton[55] reported that a diastasis recti measuring 20 centimeters allowed the uterus to be expelled through the diastasis. After placing the abdominal corset on the patient, the fetus was redirected through the birth canal. Other case studies on the treatment of diastasis recti ranged from "doing nothing" to the surgical correction of this condition.[32-34] In fact, Elbaz et al[9] contends that a patient with a diastasis recti measuring more than 4.0 centimeters is a candidate for surgical correction.

Massey[56] advocated the use of both faradic and/or galvanic transabdominal treatments in the nervous and weak female patient. A pioneer in conservative gynecology and electrotherapeutics, Massey[56] performed these treatments in 1902. Since then, electrical stimulation studies for muscle reeducation of abdominal muscles have been conducted with varying results. Despite the use of different electrical stimulation units and highly variable parameters, most of these studies demonstrated an increase in abdominal strength with the use of electrical stimulation.[37-42] Alon et al[38] compared the effects of three versus five daily treatments of electrical stimulation on 30 subjects randomly assigned to either a no treatment group, a group who received three times a week treatments of electrical stimulation with exercise, or a group who received five daily treatments of electrical stimulation with exercise. The most significant strength gains were found in the five daily treatments of electrical stimulation and exercise. In another experimental study, Alon et al[37] compared the effects of exercise and electrical stimulation on abdominal strength and endurance with four separate groups. The 30 participants were randomly divided into a control group, an electrical stimulation group, an exercise alone group, and a combination of both electrical stimulation and exercise group. Significant improvements in abdominal strength were noted primarily in the combined electrical stimulation and exercise group and in the electrical stimulation alone group. Hreka et al[40] took 38 individuals and placed them into either a control (no treatment) group or into a group receiving electrical stimulation to the abdominals. He found a significant increase in abdominal strength following four weeks of stimulation to the experimental group. There was no mention whether Hreka randomly assigned his subjects between the two groups. In another study, Iehl and his associates[41] took 14 volunteers and tested their abdominal strength before and after a five week functional electrical stimulation training program. Their findings demonstrated a 14 percent increase in abdominal strength at the conclusion of their study. Unfortunately, these results were not compared to a control group. Lastly, Aikman et al[42] found no significant differences in abdominal strength when comparing the results of 26 subjects randomly assigned to either a control, an electrical stimulation group, or an isometric sit-ups group following four weeks of training. All these studies were conducted on normal individuals. A limitation to most of these studies is revealed an extremely small sample size (10-38 participants) leaving a question as to how these findings could be generalized to a larger population.

Research studies conducted by Delitto et al[35] and Eriksson et al[36] on the effects of electrical stimulation on the quadriceps muscles following knee surgery and/or injury have reported successful outcomes in gaining strength.[35,36] In an experimental and descriptive study on the effects of electrical stimulation versus exercise alone to the thigh muscles following an anterior cruciate ligament reconstruction, Delitto et al[35] found significant improvements in the electrical stimulation group. The 20 subjects in this study were randomly assigned to one of two groups and then participated in five daily treatment sessions for three weeks.[35] Similar quadriceps muscles strength gains were also found in another experimental study conducted by Eriksson and Haggmark[36] looking at the effects of electrical stimulation versus isometric strengthening exercises. Once again, 20 subjects were randomly placed in one of two experimental treatment groups with five daily treatments for a period of three weeks.[36] These two studies shed some light on the benefits of electrical stimulation in the role of rehabilitation and muscle reeducation following an injury/surgery. Therefore, electrical stimulation combined with Noble's corrective exercise for diastasis recti may be an effective physical therapy intervention.

In this literature review, diastasis recti was defined, the functional anatomy of the anterolateral abdominal muscles was reviewed, and the incidence and etiology associated with this condition was discussed. Next, the evaluation and treatment of a diastasis recti reviewing past, current, and potential interventions was also covered. The present physical therapy treatment employs Noble's corrective exercise. Literature confirming the efficacy of this exercise in reducing or correcting a diastasis recti was not found. In addition, no reliable measurement methods for this condition have been demonstrated in the literature.

CHAPTER III

METHODS

Subjects

Nine subjects, ranging in age from 19 to 41 years, who were at least six weeks and less than two years postpartum were initially enrolled in this study. For inclusion into the study each subject also needed to exhibit a 2.0 centimeter or greater diastasis recti, not be doing abdominal strengthening exercises prior to this study, and have had a vaginal delivery. Subjects who had a cesarean section, were currently pregnant, or had a history of recurring neck, thoracic, and/or lower back pain were excluded from this study. Additionally, any subject with a history of abdominal surgery or abdominal hernia, or the presence or history of any connective tissue disease were excluded from the study. Fifteen subjects were referred for this study, with nine subjects meeting the inclusion criteria. One of the six ineligible patients had a history of a cesarean section, two were more than two years postpartum, and three demonstrated less than a 2.0 centimeter separation.

Two of the nine eligible subjects did not complete the study. One subject became pregnant two weeks into the study and the other subject had to unexpectedly move to another state.

All 15 subjects were referred and initially identified as having a diastasis recti by an OB/GYN nurse practitioner (72nd Medical Group at Tinker Air Force Base, Oklahoma) following a routine gynecological exam. Finally, all subjects read and signed a consent form approved by the Institutional Review Board at the University of Oklahoma Health Sciences Center and Headquarters Air Force, Office of the Surgeon General. At the beginning of the study, all eligible subjects filled out a questionnaire on their pre and postnatal history. Appendix A. The characteristics of each subject are included in Table 2 on page 24.

Study Design

A multiple baseline single-subject design across subjects was used to assess the effectiveness of Noble's corrective exercise (Group I) and electrical stimulation combined with Noble's corrective exercise (Group II) in reducing a diastasis recti. This design employs the basic A-B format with each subject acting as her own experimental control. In this study, Subject 1 in each of the two experimental groups remained in the baseline phase until at least three stable data points were collected, after which treatment was initiated.[57] Once in the treatment phase, stability of data points was interpreted as either a stable level response or a constant deceleration (a reduction in the width of the diastasis recti), of at least three data points when compared to the baseline points. When treatment data were stable for Subject I, treatment was initiated for Subject 2. This process was then repeated on a staggered basis for the remaining two subjects in Group I and the remaining subject in Group II.

The seven eligible subjects were counterbalanced to one of two treatment groups according to the severity of their diastasis recti then randomly assigned to a subject position. This ensured that an evenly distributed number of minimal to moderate diastasis recti was assigned to each experimental group.

TABLE 2. CHARACTERISTICS FOR GROUP I AND GROUP II SUBJECTS

	Group I				Group II		
	Subject 1	Subject 2	Subject 3	Subject 4	Subject 1	Subject 2	Subject 3
Age (years)	30	21	27	19	41	32	24
Race	Caucasian	Caucasian	Caucasian	African American	African American	Caucasian	Caucasian
Total Weight gained last pregnancy	43#	61#	50#	30#	36#	30#	25#
Weight After pregnancy	155#	142#	180#	200#	152#	135#	140#
Present weight	141#	130#	170#	185#	126#	125#	133#
Present height	63"	58"	66.5"	65"	62"	63"	64"
No. of pregnancies/deliveries	5/5	1/1	1/1	2/2	1/1	2/2	1/1
Breastfeeding	YES	NO	YES	NO	NO	NO	NO
Postpartum status	15 months	5 months	7 weeks	20 months	16 months	11 months	6 months
Birth weight of child	9# 3oz	6# 13oz	10# 5oz	7# 2oz	6# 8oz	7# 5oz	4# 3oz
Birth Control	Vasectomy	BCP	Condom	None	Vasectomy	Tubal ligation	BCP
LBP Rating	7	3	5	4	1	3	2
Diastasis Location	Above	At umbilicus	Above	At umbilicus	At umbilicus	At umbilicus	At umb

Weight measured in pounds (#) and ounces (oz) Birth Control Pills (BCP)
Height measured in inches (") Umbilicus (umb)
Low back pain (LBP) rating during pregnancy (excluding labor pain) measured on a 0 = no pain to 10 = severe, debilitating pain scale

Treatment

Exercise Alone - Group I

Each subject assigned to Group I performed Noble's diastasis recti correction exercise, as illustrated in Figure 5, during the treatment phase. In this exercise, each subject performed a head raise while maintaining a posterior pelvic tilt. In addition, a bed sheet was wrapped around her midsection and was gently pulled across her body during the contraction phase of the exercise to realign the rectus muscles towards the midline. One day prior to starting the treatment phase, a maximum number of repetitions was determined. This exercise regime was performed three times weekly under the direction of the primary investigator for a 6 week period. Measurement of the diastasis recti by ultrasound imaging was performed once a week.

Figure 5. A subject performing the diastasis recti correction exercise with a bed sheet.

Exercise Combined with Electrical Stimulation - Group II

Each subject randomly assigned to Group II also performed Noble's diastasis recti correction exercise in combination with neuromuscular electrical stimulation. The maximum number of repetitions was also determined at least one day prior to starting the treatment phase. A Chattanooga VMS II unit was used with this group with bipolar placement of 3X10 centimeter electrodes perpendicular to the rectus abdominis muscles and placed 5.0 centimeters above and below the umbilicus. An alcohol skin preparation before and after applying the electrodes was performed each treatment session. Electrical stimulation parameters established by and similar to those used by Alon et al[37-39] included: biphasic symmetrical pulse waveform, 200 *u*sec phase duration and a 50 pulses per second pulse rate. In addition, an 8 second contraction on time, 4 second off time, and a 2 second ramp up time was employed. Stimulation intensity was according to the subject's tolerance. Each treatment lasted 20 minutes, with each subject performing the established number of repetitions with the electrical stimulation. Treatment sessions were scheduled and monitored by the primary investigator three times weekly for at least 6 weeks with remeasurement of the diastasis each week by ultrasound imaging.

Determining Maximum Number of Repetitions

Before starting the treatment phase, each participant performed a partial curl up, holding for 5 seconds and resting for 5 seconds, repeating the curl ups until the subject could no longer lift the spine of the scapula away from the table. This determined the maximum number of repetitions (MNR) the subject could comfortably perform. Alon et al[37,38] developed and used this MNR protocol in two separate studies comparing the effects of electrical stimulation and exercise on abdominal strengthening. He and his colleagues also used a simple formula for increasing the number of repetitions each week by 10 to 20 percent, which was also used in this study.[38] This gradual increase in repetitions was intended to provide sufficient overloading to the rectus abdominis muscles to promote strengthening. Table 3 outlines the exercise progression protocols while Table 4 shows the MNR for each subject in Group I and Group II.

Table 3. Exercise progression protocols for Group I and Group II subjects.

Week	Hold	Relax	Repetitions
1	5 sec.	5 sec.	MNR + 0.1 MNR = R1
2	"	"	R1 + 0.2 R1 = R2
3	"	"	R2 + 0.2 R2 = R3
4	"	"	R3 + 0.2 R3 = R4

MNR = Maximum number of repetitions. R1 = repetitions for week 1;etc..
Sec = seconds

Table 4. Maximum Number of Repetitions (MNR) for each subject in Group I and Group II

Group I	MNR	Group II	MNR
Subject 1	35	Subject 1	25
Subject 2	40	Subject 2	38
Subject 3	30	Subject 3	30
Subject 4	42		

Instrumentation

A diagnostic ultrasound machine (Acuson 128) with a 7.0 MHz frequency linear-array transducer was used for determining the exact location and severity of the diastasis recti, that is, the widest area of separation at the linea alba along the full length of the rectus abdominis muscles. The ultrasound unit was certified safe by the Medical Equipment Repair Committee (MERC) prior to its use in this study. A sonographer from the 72nd Medical Group at Tinker AFB, Oklahoma performed all ultrasound imaging. To reduce both diagnostic suspicion and interpretation bias, all of the ultrasound images were recorded by the primary investigator and the accuracy of these measurements was determined by an independent sonographer from the University of Oklahoma, Department of Radiologic Technology.

A clinical neuromuscular electrical stimulator (Chattanooga Intellect VMS II) was used for the group receiving electrical stimulation and exercises. This stimulator was also calibrated and certified by the MERC prior to its use in this study.

Procedure

All 15 subjects were referred and initially identified as having a diastasis recti by an OB/GYN nurse practitioner following a routine gynecological exam. After reading and signing the consent form, each subject filled out a questionnaire on their pre and postnatal history. See Appendix A. To determine if a diastasis recti existed, each subject was positioned supine with hips and knees flexed in a hooklying position with both feet supported on a flat surface. The subject then performed a head raise. The finger-width measurement of the diastasis recti was then accomplished by the primary investigator placing her fingers horizontally across the linea alba and determining how many fingers fit into the space between the medial borders of the two rectus abdominis muscles 4.5 cm above, 4.5 cm below, and at the umbilicus.

Each subject was then referred for the ultrasound measurement. A standard plastic ruler marked in centimeters was used to measure from the superior border of the umbilicus to 4.0 and 6.0 cm above and from the inferior border of the umbilicus to 4.0 and 6.0 cm below the umbilicus. Next, these four areas were marked with indelible ink in order to standardize each weekly measurement as well as serving as a boundary for the electrode placements. See Figure 6. These markings allowed the 1.5 cm ultrasound transducer head to remain within the boundaries of these markings. The sonographer then applied ultrasound gel to the subjects abdomen and began scanning the same three areas for measurement, that is, 5.0 cm above, at, and 5.0 cm below the umbilicus. Once the linea alba was clearly identified and imaged on the screen, the subject performed a head raise as described above. The medial borders of the left and right rectus abdominis muscles were used for the end points for the measurement. To quantify the separation at the linea alba, a caliber was placed at each border and a digital measurement (in centimeters) of the

the umbilicus, the area with the largest separation was used for analysis in this study. The primary investigator recorded all ultrasound measurements.

Figure 6. a) Establishing boundaries for the diagnostic ultrasound measurement 5.0 centimeters above and below the umbilicus. b) Diagnostic ultrasound measurement above the umbilicus. c) Electrode placement for Group II subjects.

Intrarater Reliability

To assess intrarater reliability of the diagnostic ultrasound images, opaque tape was applied to the portion of the screen where the digital readout was displayed, masking all measurement values from the sonographer, from the subject, and from the primary investigator. The measurements were recorded by the primary investigator from a photographic copy. The area with the largest separation was measured twice with a five minute break between trials. Intrarater reliability was determined from these repeated measures that were obtained each week. The first measurement trial was the one plotted on the graph. An intraclass correlation coefficient (ICC 1,1) was used to determine reliability for the diagnostic ultrasound imaging of the width of the diastasis recti.[57] Reliability was calculated on 67 percent of all measurements taken. The ICC was 0.98 for measurements (n= 15) taken above the umbilicus, 0.79 for measurements (n=35) taken at the umbilicus, and 0.95 for the combined test/retest measurements. None of the subject's widest separation was below the umbilicus.

At the conclusion of the study, an independent sonographer rated 251 photos produced from all measurements taken at the three abdominal sites. The quality assurance guidelines established for this peer review of ultrasound imaging included rating the accuracy of the two caliber placements on a scale of 2 to 5. Table 5 describes the rating scale used. Of the 251 photos reviewed, 86 (34%) received a 5 rating, 89 (36%) received a 4 rating, 50 (20%) received a 3 rating, and 26 (10%) received a two rating. Table 6 shows the individual results from photos rated at the three abdominal sites.

TABLE 5. Ultrasound Rating Scale

Rating	Description of rating
5	Muscle endpoints are well displayed with calibers accurately placed
4	Muscle endpoints are well displayed with caliber placement ± 3 millimeters
3	Both endpoints may not be well displayed or caliber placements are questionable
2	Image does not justify measurement

TABLE 6. Ultrasound ratings above, at, and below the umbilicus.

	Rating	Photos receiving rating	Percentage
Above umbilicus	5	42	53
	4	10	13
	3	23	28
	2	5	6
Total		80	100
Umbilicus	5	28	25
	4	43	38
	3	22	19
	2	21	18
Total		114	100
Below Umbilicus	5	16	28
	4	36	63
	3	5	9
	2	0	0
Total		57	100

Data Analysis

Weekly measurements were plotted on each subject's graph. A split-middle procedure, followed by visual analysis of data level and trend was used to interpret the Group I and Group II baseline and treatment phases, as well as differences between the two phases.[58,59] Descriptive statistics, including the mean, median, range, standard deviation, minimum, maximum, and the overall mean difference between baseline and treatment phases were also calculated for the largest separation found at the beginning of the study.

CHAPTER IV

RESULTS

Group I and Group II Findings

A split-middle procedure and visual analysis of data for Group I, Subject 1 showed a dramatic level change in the width of the diastasis recti within two weeks of the treatment phase. (See Figure 7). The remaining three subjects in Group I showed a steady downward trend in the width of the diastasis recti once the treatment phase was initiated. Subject 1 and Subject 3 had the widest separation above the umbilicus. Subjects 2 and 4 demonstrated the widest separation at the umbilicus. Table 7 summarizes descriptive statistics for baseline and treatment phases for both groups.

A split-middle procedure and visual analysis of data for Group II, Subjects 1 and 2 showed an overall downward trend and Subject 3 demonstrated a level change in the width of the diastasis recti, once the treatment phase was started. (See Figure 8). All subjects in this group demonstrated the widest separation at the umbilicus. Subject 1 underwent six weeks of treatment before trend a change was noted.

TABLE 7. DESCRIPTIVE STATISTICS FOR BASELINE AND TREATMENT PHASES FOR GROUP I AND GROUP II SUBJECTS

	Group I				Group II		
	Subject 1	Subject 2	Subject 3	Subject 4	Subject 1	Subject 2	Subject 3
Total number of baseline measurements	4	6	6	6	3	4	5
Total number of treatment measurements	7	5	6	5	6	6	6
Baseline mean ($\overline{X}_B$)	4.30 cm	2.40 cm	3.57 cm	2.17 cm	2.37 cm	2.70 cm	2.84 cm
Treatment mean ($\overline{X}_T$)	1.91 cm	1.70 cm	2.73 cm	1.52 cm	2.05 cm	2.18 cm	1.73 cm
$\overline{X}_B - \overline{X}_T$	2.39 cm	0.70 cm	0.84 cm	0.65 cm	0.32 cm	0.52 cm	1.11 cm
Baseline median	4.25 cm	2.40 cm	3.50 cm	2.20 cm	2.40 cm	2.70 cm	2.90 cm
Treatment median	1.70 cm	1.60 cm	2.65 cm	1.40 cm	2.05 cm	2.15 cm	1.70 cm
Baseline standard deviation	0.14 cm	0.09 cm	0.10 cm	0.10 cm	0.06 cm	0.08 cm	0.19 cm
Treatment standard deviation	0.67 cm	0.34 cm	0.40 cm	0.28 cm	0.27 cm	0.32 cm	0.10 cm
Baseline minimum/maximum	4.20/4.50 cm	2.30/2.50 cm	3.50/3.70 cm	2.00/2.30 cm	2.30/2.40 cm	2.60/2.80 cm	2.50/3.00 cm
Treatment minimum/maximum	1.50/3.40 cm	1.30/2.10 cm	2.20/3.30 cm	1.20/1.90 cm	1.80/2.30 cm	1.80/2.60 cm	1.60/1.90 cm
Baseline range	0.30 cm	0.20 cm	0.20 cm	0.30 cm	0.10 cm	0.20 cm	0.50 cm
Treatment range	1.90 cm	0.80 cm	1.10 cm	0.70 cm	0.50 cm	0.80 cm	0.30 cm

cm = centimeters B = Baseline T = Treatment

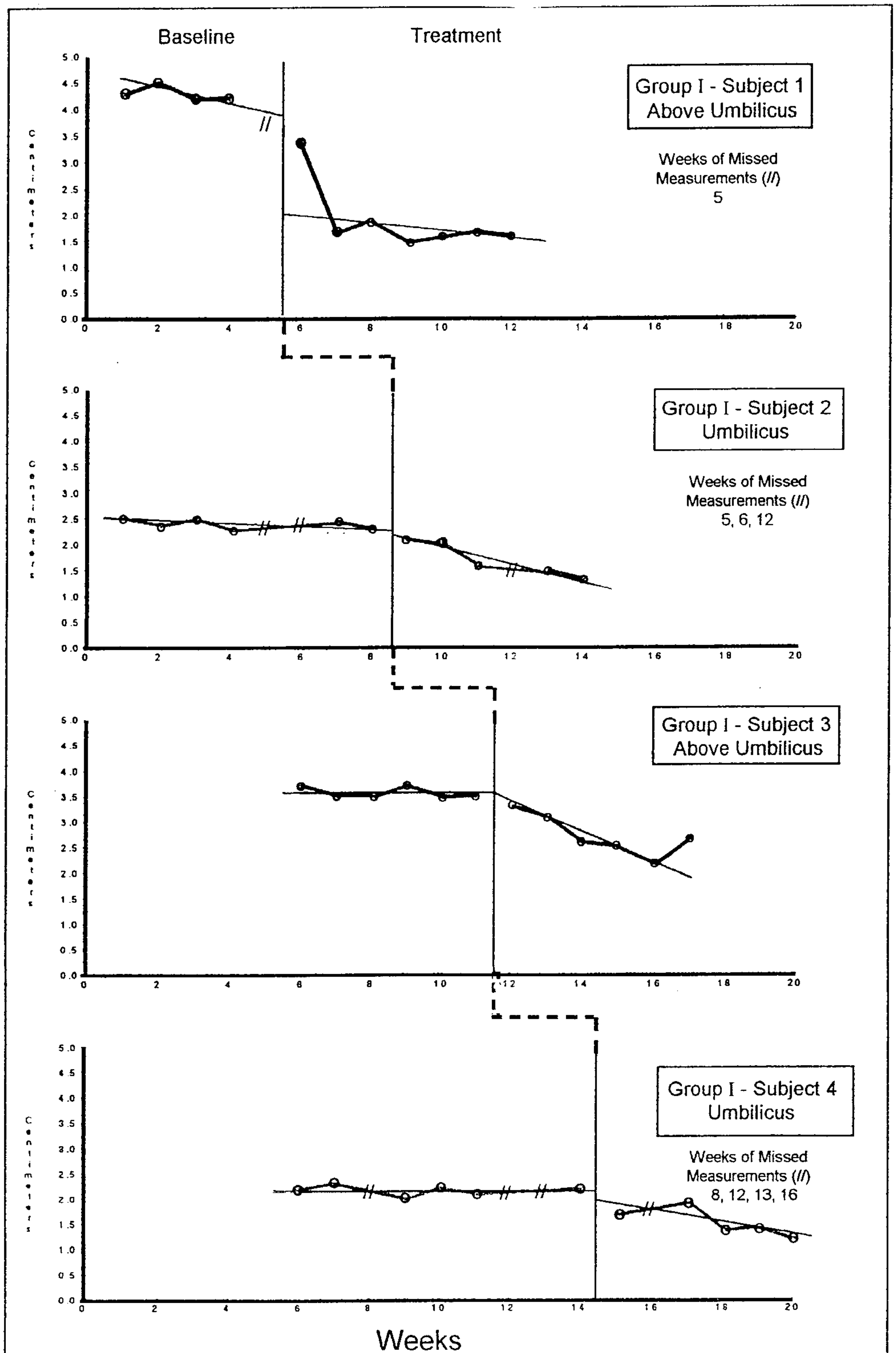


Figure 7. Split-middle lines for trend analysis of Diastasis Recti on Group I Subjects comparing baseline and treatment measurements.

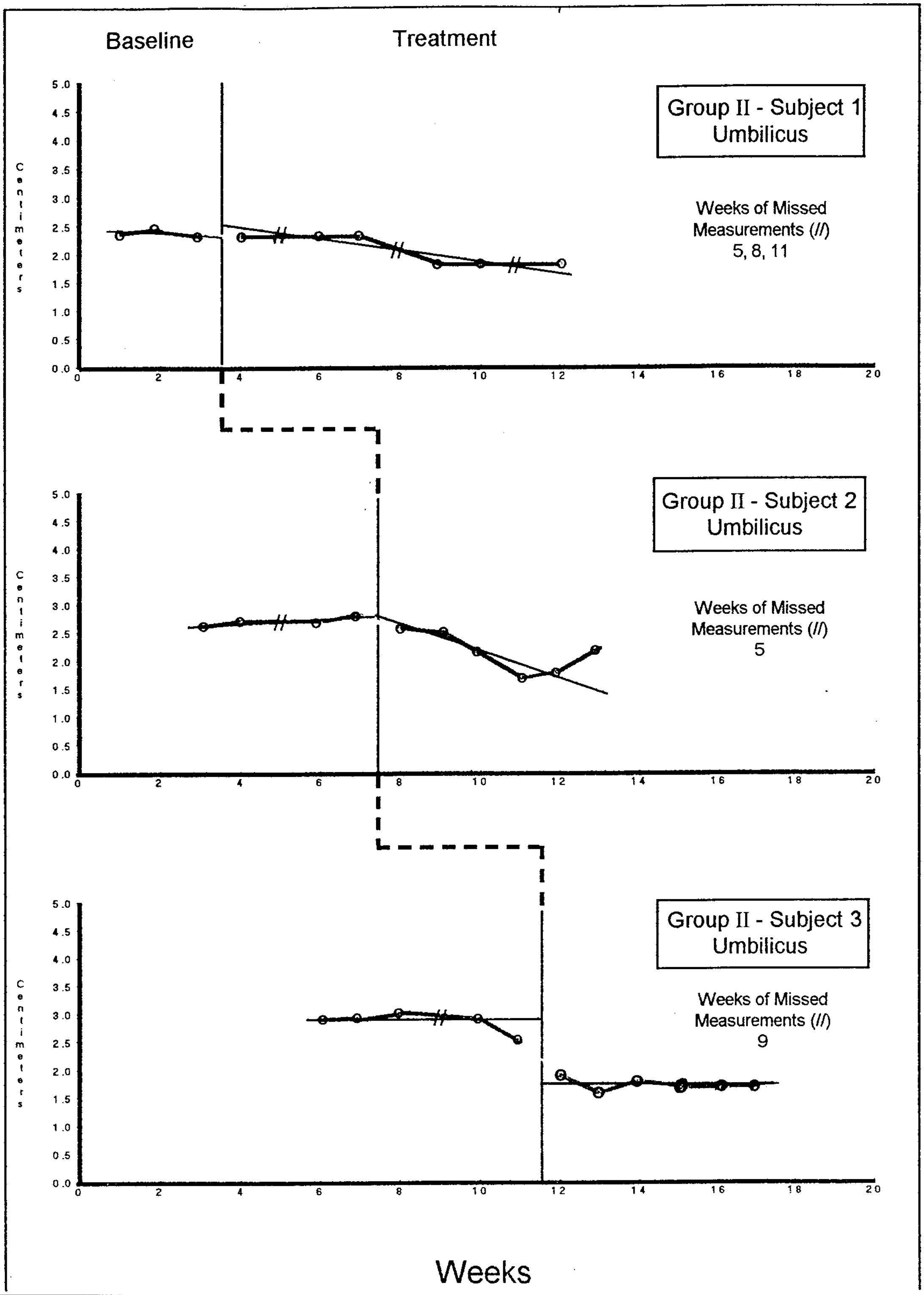


Figure 8. Split-middle lines for trend analysis of Diastasis Recti on Group II Subjects comparing baseline and treatment measurements.

Collective Findings

Ultrasound measurements at all three sites, 5.0 cm above the umbilicus, 5.0 cm below the umbilicus, and at the umbilicus were taken on each subject each week. These three data points are shown in Figures 9 - 15 for both baseline and treatment phases for each subject in both groups.

Group I, Subjects 1 and 3, who demonstrated the widest separation above the umbilicus, also demonstrated a 4.2 cm and 3.5 cm separation at the umbilicus. For Group I, Subject I, the width of the diastasis recti at the umbilicus showed a level change during the treatment phase. Group I, Subject 1 still demonstrated a 3.2 cm diastasis at the umbilicus after seven treatment sessions. For Group I, Subject 3, the width of the diastasis recti was essentially unchanged between baseline and treatment phases for measurements taken below and at the umbilicus. Group I, Subject 3 exhibited a 2.9 cm diastasis recti at the umbilicus after six exercise treatment sessions. Group I, Subject 2 exhibited stable data points above the umbilicus throughout the baseline and treatment phases with a gradual downward trend for the umbilicus and below the umbilicus measurement data during the treatment phase. Finally, Group 1, Subject 4 demonstrated a downward trend in all three measurements at, above, and below the umbilicus once she began the treatment phase.

Group II, Subject 2 demonstrated a slight upward trend for the umbilicus and above the umbilicus measurements for her last two treatments (at weeks

12 and 13). Her last treatment measurement revealed a 2.1 cm diastasis at both the umbilicus and above the umbilicus. Group II, Subjects 1 and 3 demonstrated minimal variability in their data points at and below the umbilicus measurement sites in both the baseline and treatment phases.

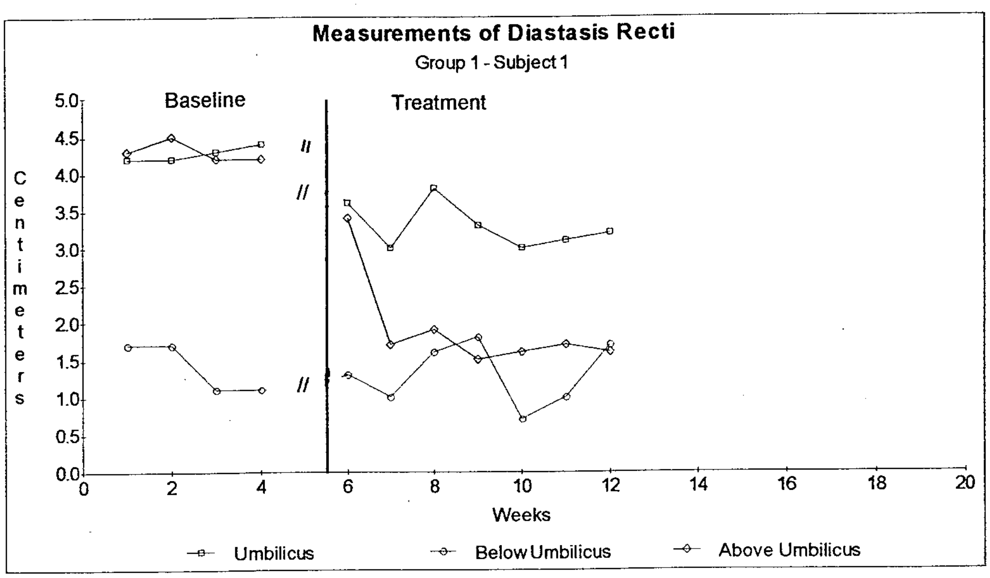


Figure 9. Graph of baseline and treatment measurements at all three abdominal sites for Group 1, Subject 1

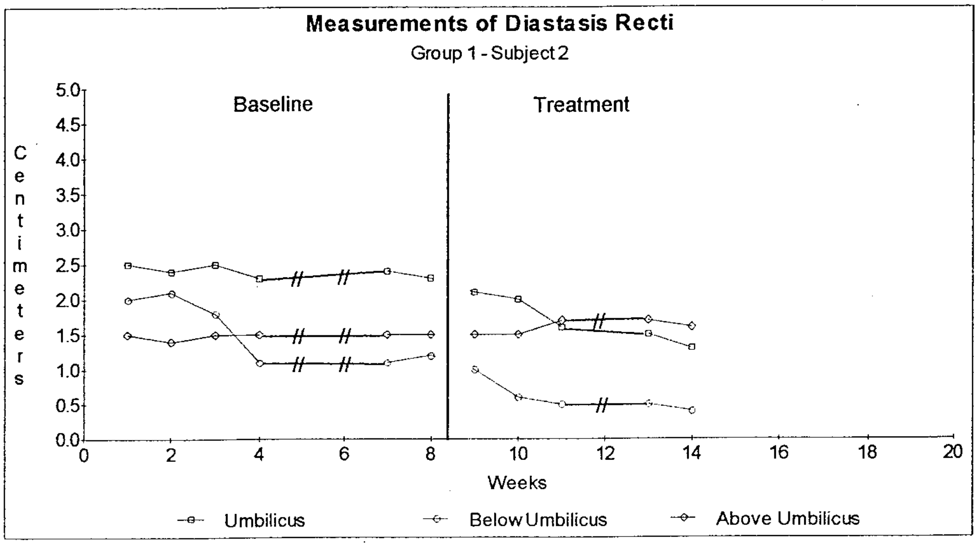


Figure 10. Graph of baseline and treatment measurements at all three abdominal sites for Group I, Subject 2.

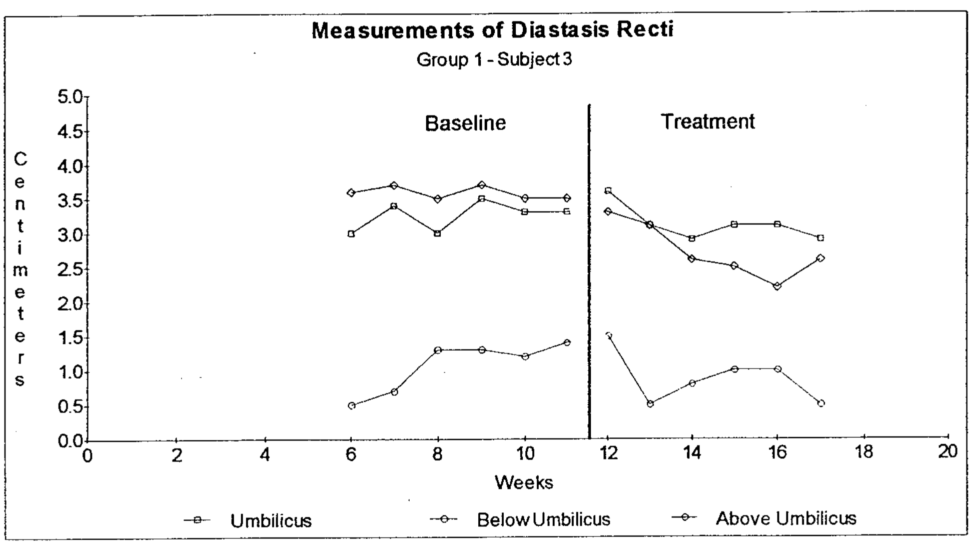


Figure 11. Graph of baseline and treatment measurements at all three abdominal sites for Group 1, Subject 3.

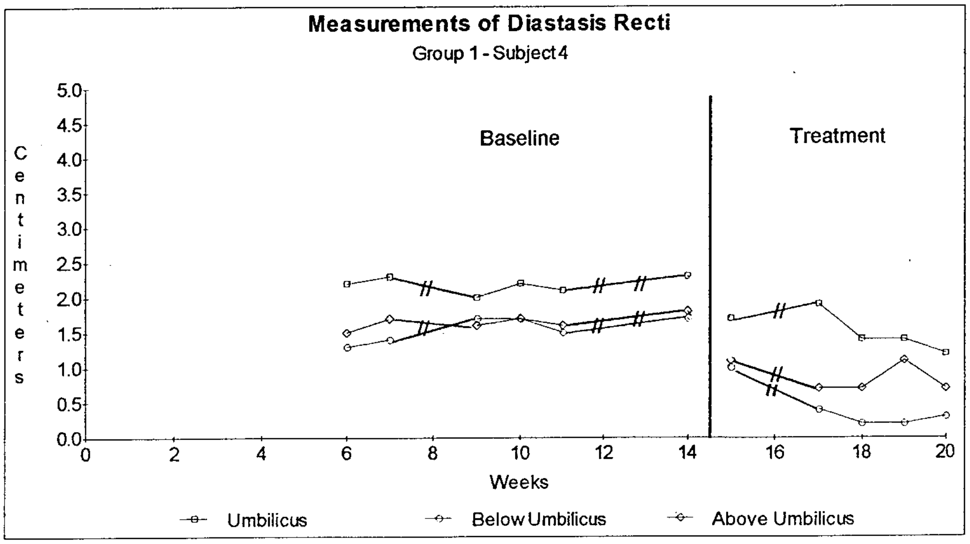


Figure 12. Graph of baseline and treatment measurements at all three abdominal sites for Group 1, Subject 4.

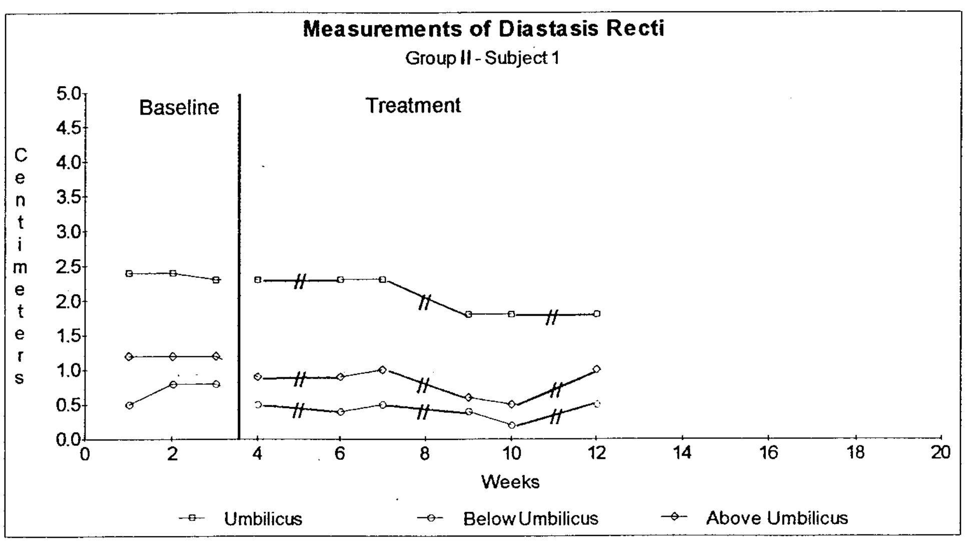


Figure 13. Graph of baseline and treatment measurements at all three abdominal sites for Group II, Subject 1.

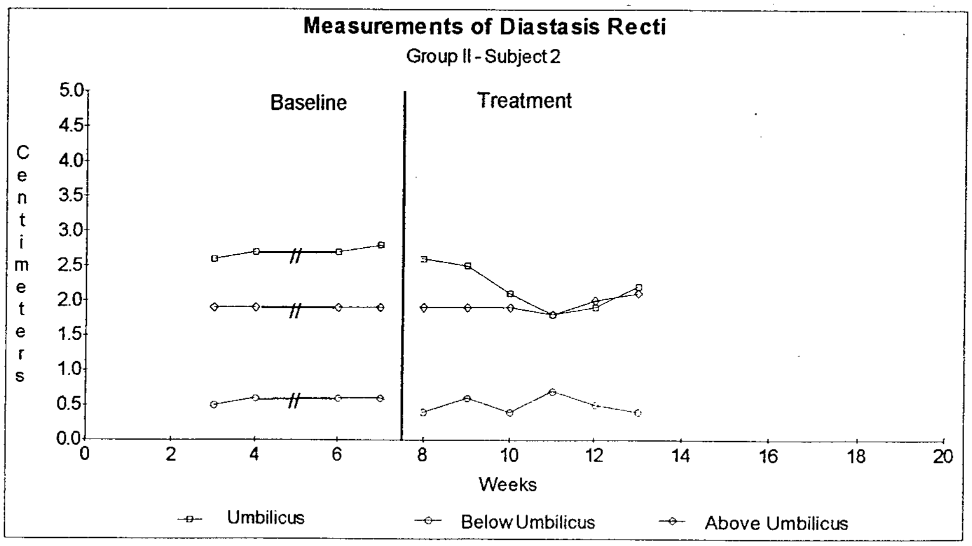


Figure 14. Graph of baseline and treatment measurements at all three abdominal sites for Group II, Subject 2.

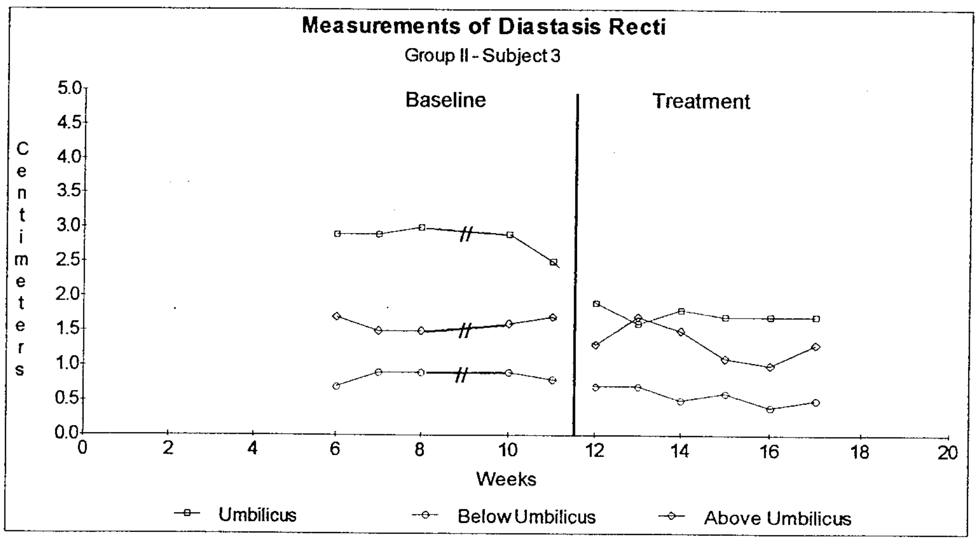


Figure 15. Graph of baseline and treatment measurements at all three abdominal sites for Group II, Subject 3.

CHAPTER V

DISCUSSION

This study demonstrated that Noble's corrective exercise was beneficial in the reduction of a diastasis recti, whether combined with electrical stimulation or performed alone, for all seven subjects. The most pronounced reduction in the width of the diastasis recti occurred in those subjects exhibiting a 2.8 cm or larger separation initially. Clinically, a 0.32 cm reduction, as demonstrated by Group II, Subject I, does not appear to be a successful outcome. However, when looking at the final measurement (diastasis of 1.8 cm), one may consider this to be a successful outcome. In fact, clinical outcome effectiveness of these two different interventions needs to be operationally defined. Normal variations of one to two centimeters of separation may occur along the entire length of the linea alba.[5] Referring back to Table 7, reductions in the width of the diastasis recti ranged from .65 cm to 2.39 cm for the four subjects in Group I. Group II subjects exhibited overall reductions ranging from .32 cm to 1.11 cm. Group I, Subject 3 had an overall reduction in the width of the diastasis recti of .84 cm, however still demonstrated a clinically significant separation (greater than 2.0 cm) at the conclusion of the treatment phase.

All seven subjects initially exhibited a separation greater than 2.0 cm at the umbilicus, which differs from findings by Boissonnault and Blaschak[24] on the location of a diastasis recti. She and her associate reported that 53 percent of the diastasis recti were located at the umbilicus with 36 percent found above and 11 percent below the umbilicus. These findings are consistent with this investigators research and the studies conducted by Boissonnault and Blaschak regarding the anatomical make-up of the aponeurosis of the abdominal wall. Above the arcuate line, the aponeurosis of the external oblique joins the anterior layers of the rectus sheath, whereas the internal oblique aponeurosis splits to form anterior and posterior layers of the sheath. Finally, the transversus abdominis aponeurosis joins the posterior layer. However, below the arcuate line, the three aponeuroses join and fuse anteriorly, thereby providing more support to the lower abdomen.[5,11,43,44]

When assessing the graphed measurements for all three sites, Group I Subject 1 demonstrated increases in all 3 data measurements during the treatment phase at week 8. It is not known why this occurred, but possible causes may have been related to this subject's menstrual cycle and/or food intake prior to coming in for the ultrasound measurement. A similar increase in measurement data occurred the first week of the treatment phased at and below the umbilicus with Group I, Subject 3 at week 12. Group I, Subject 3 also demonstrated a 0.5 cm increase in her last treatment measurement above the umbilicus in week 17. Group I, Subjects 1 and 3 exhibited a 3.2 cm and 2.9 cm diastasis at the umbilicus at the conclusion of this study. Both of these subjects were the only two who were currently breastfeeding, which may suggest some form of a hormonal influence/imbalance. In addition, both of these subjects had the largest weight babies.

Group II, Subject 1 received six weeks of treatment before a noticeable trend change occurred. During the remaining three weeks of treatment she had a stable 1.8 cm separation which is deemed a normal separation. This was the oldest subject in this study which may account for the delayed effect of the treatment.

An interesting result of using diagnostic ultrasound imaging was the ability to see muscle asymmetries in the rectus abdominis suggesting a possible rib and/or pelvic dysfunction. All four anterolateral abdominal muscles have origins or insertions onto the ribs and pelvis. No studies have been performed looking at the relationship of a diastasis recti and lumbo-pelvic-hip dysfunction. If a relationship does exist, could muscle energy techniques and/or joint mobilization also help in reducing a diastasis recti?

Another factor that may have affected this study was whether or not the subjects came in for their weekly ultrasound measurements. The subjects usually kept their appointments, however, severe weather, spring breaks, job related responsibilities, sick children, and out-of-town trips were some of the reasons for missing. However, all subjects in both groups complied with the three times per week exercise or exercise combined with electrical stimulation. A group research design using before (baseline) and after (treatment) measures with a larger sample size may help with the compliance of the ultrasound measurements, as only two measurements would be required.

Noble's exercise protocols were modified to strengthen the research design. Establishing a maximum number of repetitions for each subject at the beginning of the treatment phase was received well by each subject. Many of the subjects voiced apprehension about performing 50 repetitions a day as required by Noble's[3] protocol. Because the sample size was small, no relations could be found between the size or severity of a diastasis recti demonstrated by these seven subjects and characteristics such as, race, age, birth weight of the baby, the weight gained during the pregnancy, and parity.

No gold standard exists at this time for the most reliable and valid way to measure a diastasis recti. In this study, diagnostic ultrasound was found to be highly reliable (ICC = 0.98) for above the umbilicus measurements, however, all seven subjects in this study exhibited a diastasis recti at the umbilicus with only two demonstrating greater than 2.0 cm separation above the umbilicus. The intraclass correlation coefficient for measurements at the umbilicus was 0.79. More research is needed to substantiate the reliability of this measurement method. Diagnostic ultrasound has opened a window into the evaluation of musculoskeletal dysfunction. Clinical uses for a diagnostic ultrasound in interpreting and monitoring soft tissue dysfunction are already well documented in the literature.[60-66] Recent physical therapy literature also identified diagnostic ultrasound as a valuable resource in monitoring the healing of a chronic shoulder condition during rehabilitation.[68]

Limitations of This Study

In this study design, double blinding was not used for ethical and safety reasons. Informing each potential subject as to what treatment groups they could be randomly assigned outweighed the need to blind the subjects from this information. To avoid diagnostic suspicion bias, in which knowledge of the patient's treatment influences the intensity of the search or the results of the search for a particular outcome, the ultrasound readings were masked from the sonographer, from each subject, and from the primary investigator.[68] However, the primary investigator also acted as the recorder. Ideally, all measurements should have been recorded by an independent recorder. To help minimize diagnostic suspicion bias, this study did use an objective test, in this case, the diagnostic ultrasound imaging and these measurements were repeated at fixed intervals. To avoid interpretation bias, all outcome data should have been analyzed by an outcome classification committee.[68] This was not feasible in this study due to the increased time and cost to obtain additional personnel.

Other limitations of this study centered around the ultrasound transducer. In this study, a 7.0 MHz frequency linear-array transducer was used. According to Kaplan et al,[18] a higher frequency transducer in the 7.5 to 10 MHz range provides the best resolution for imaging superficial soft tissue structures. The resolution when using the 7.0 MHz transducer may have contributed to the 2 and 3 ratings by the independent sonographer. The 10 MHz transducer produces a better quality image when imaging superficial soft tissue structures. In the case of an obese individual with more than 2.0 cm of subcutaneous fat, diagnostic ultrasound may not be the best choice in determining a diastasis recti no matter what transducer is used. In fact, one obese subject was excluded from this study because the rectus muscles could not be identified by ultrasound imaging. Another potential problem with the ultrasound is that a direct measurement could not be obtained at the umbilicus which may account for the 0.79 ICC rating. The umbilicus traps air, which reflects the ultrasound beam. This prevents penetration to and imaging of the superficial structures, therefore all measurements at the umbilicus were directed towards the superior border. The final problem with ultrasound imaging occurred when a diastasis greater than 3.5 cm was measured. The field of view is approximately 3.7 cm wide, therefore any diastasis measuring greater than 3.5 cm required the sonographer to use a split screen. This limited field of view was insufficient to cover the distance of the separation. The area imaged at one time is limited by the area interrogated by the sound beam. This beam is dependent on the size and shape of the transducer and dimensions of the beam itself. The use of the split screen may have also contributed to the lower agreement rate found at the umbilicus as well as, played a factor in the 2 and 3 ratings assessed by the independent sonographer.

Limitations to using a multiple baseline single-subject design across subjects is the time required to complete a study and generalizability is not a strong point for this particular research design. Lastly, follow up ultrasound measurements after the subjects stopped their exercises was not accomplished nor identified a priori. Follow up measurements after the subjects discontinued exercise would have determined the long term effects of exercise and/or electrical stimulation.

Recommendations for Future Studies

Implications for future studies using diagnostic ultrasound may focus on obtaining a baseline of women of childbearing age who have never been pregnant to determine if the normal separation at the linea alba is actually one to two centimeters. Other studies may investigate intrarater/interrater agreement between diagnostic ultrasound and the finger-width method for measuring a diastasis recti. Research examining possible relationships between rib and/or pelvis dysfunction and the severity of a diastasis recti may also be helpful. In addition, further research into the prevention and etiological factors associated with a diastasis recti needs to be conducted, as well as studies to determine if hormonal influences have a direct impact on this condition. Clinical trials looking at different electrical stimulation parameters or comparing daily versus three times per week exercise regimes in the reduction of a diastasis recti would be helpful. Lastly, a study on the long term effects of Noble's corrective exercise in the reduction of a diastasis recti for patients with both acute and chronic conditions could be investigated.

CHAPTER VI

CONCLUSIONS

All seven subjects in this multiple baseline single-subject research design demonstrated a reduction of a diastasis recti after one of two treatments were introduced. Four subjects in Group I received Noble's diastasis recti corrective exercise three times a week for six weeks. Three subjects in Group II received electrical stimulation combined with Noble's exercise. All subjects exhibited a diastasis recti at the umbilicus and two of the seven demonstrated a separation above the umbilicus. Those subjects demonstrating a diastasis larger than 2.8 cm initially showed the greatest improvement. To determine reliability of diagnostic ultrasound as an objective measurement method, an ICC was 0.98 for measurements taken above the umbilicus, 0.79 for measurements taken at the umbilicus, and 0.95 for the combined test/retest measurements. This study showed that treatment by either exercise alone or exercise combined with electrical stimulation can reduce a diastasis recti abdominis in the patient who was at least six weeks and less than two years postpartum. Diagnostic ultrasound was shown to be fairly reliable for measurements taken at the umbilicus and exceptionally reliable for measurements taken above the umbilicus.

In conclusion, it is hoped that this study provided some insight on how to objectively identify and measure and then effectively treat a patient with a postpartum diastasis recti. The potential consequences of a diastasis recti may include a predisposition to lumbo-pelvic-hip dysfunction and ineffective visceral functions, such as, coughing, urination, delivering a baby, or exhaling. The role of the physical therapist in the management of this musculoskeletal dysfunction should also include education to the medical community on the potential problems associated with a diastasis recti.

Clinical implications from this study revealed that women, whose postpartum status is greater than 6 weeks but less that two years, can benefit from exercise alone or exercise combined with electrical stimulation in reducing a diastasis recti. Special consideration should be extended to the older patient, as well as being aware of how hormonal influences may affect treatment outcomes during rehabilitation. Additional studies are needed to determine effective treatments to all patients with this condition. Clinical trials on the use of abdominal supports in combination with established treatments for patients with a chronic diastasis recti could also be investigated.

List of References

1. Crossen HS. *Diagnosis and Treatment of Disease of Women*. 3rd ed. St Louis, Mo: CV Mosby Co; 1916.

2. Iason AH. *Hernia*. York: The Maple Press Co; 1941.

3. Noble E. *Essential Exercises for the Childbearing Year*. 3rd ed. Boston, MA: Houghton Mifflin Co; 1988.

4. Ponka JL. *Hernias of the Abdominal Wall*. Philadelphia, Pa: WB Saunders; 1980.

5. Williams PL, Warwick R. *Gray's Anatomy*. 36th ed. Philadelphia, Pa: WB Saunders; 1980.

6. Laban MM. Collagen tissue: implications of its response to stress in vitro. *Arch Phys Med & Rehab*. 1962;43:461-464.

7. MacLennan AH, Nicholson R, Green RC. Serum relaxin in pregnancy. *Lancet*. 1986;2:241-243.

8. Szlachter BN, Quagliarello J, Jewelewicz R, et al. Relaxin in normal and pathogenic pregnancies. *Obstet & Gyn*. 1982;59(2):167-170.

9. Elbaz JS, Flageul G. *Plastic Surgery of the Abdomen*. New York, NY: Masson Publishing USA, Inc.; 1979.

10. Ranney B. Diastasis recti and umbilical hernia causes, recognition, and repair. *So Dakota Jour Med*. 1990;43(10):5-8.

11. Kendall FP, McCreary EK, Provance PG. *Muscles Testing and Function with Posture and Pain*. 4th ed. Baltimore, Md: Williams and Wilkins; 1993.

12. Morris JM, Lucas DB, Bresler B. The role of the trunk in stability of the spine. *Jour Bone & Joint Surg*. 1961;43-A(3):327-351.

13. Porterfield JA, DeRosa C. *Mechanical Low Back Pain*. Philadelphia, Pa: WB Saunders; 1991.

14. Tesh KM, Dunn JS, Evans JH. The abdominal muscles and vertebral stability. *Spine*. 1987;12(5):501-508.

15. Webster JC. *Textbook of Diseases of Women*. Philadelphia, Pa: WB Saunders; 1907.

16. Bursch SG. Interrater reliability of diastasis recti abdominis measurement. *Phys Ther.* 1987;67(7):1077-1079.

17. Merritt CRB, Bluth EI. Techniques for diagnostic imaging. Computed tomography, ultrasound, and magnetic resonance imaging. *Diagnostic Imaging*. 1985;77(6):56-73.

18. Kaplan PA, Matamoros A, Anderson JC. Sonography of the musculoskeletal system. *AJR*. 1990;155:237-245.

19. Young A, Hughes I. Ultrasonography of muscle in physiotherapeutic practice and research. *Physiother.* 1982;68(6):187-190.

20. Hicks JE, Shawker TH, Jones BL, et al. Diagnostic ultrasound: its use in the evaluation of muscle. *Arch Phys Med Rehabil*. 1984;65:129-131.

21. Bellisari A, Roche AF, Siervogel RM. Reliability of B-mode ultrasonic measurements of subcutaneous adipose tissue and intra-abdominal depth: comparisons with skinfold thickness. *Internat'l Jour Obesity & Rel Metabolic Disorders.* 1993;17(8):475-480.

22. DiGiandomenico V, Filippone A, Basilico R, et al. Reproducibility of ultrasound measurement of pancreatic size with new advanced high resolution dynamic image scanners. *Jour Clin Ultrasound*. 1993;21(2):77-86.

23. Graf R. Hip sonography-how reliable? sector scanning versus linear scanning? dynamic versus static examination? *Clin Ortho & Rel Research.* 1992;281:18-21.

24. Boissonnault JS, Blaschak MJ. Incidence of diastasis recti abdominis during the childbearing year. *Phys Ther.* 1988;68(1):1082-1086.

25. Dale B, Roeber J. *The Pregnancy Exercise Book.* New York, NY: Pantheon Books; 1982.

26. O'Connor LJ, Gourley RJ. *Obstetrics and Gynecologic Care in Physical Therapy.* Thorofare: Slack Inc; 1990.

27. Polden M, Mantle J. *Physiotherapy in Obstetrics and Gynaecology.* Oxford: Butterworth-Heinemann Ltd; 1992.

28. Olds SB, London ML, Ladewig PA. *Maternal-New-born Nursing. A Family-Centered Approach.* 2nd ed. Menlo Park, Ca: Addison-Wesley Publishing Co; 1984.

29. Bennett VR, Brown LK. *Myles Textbook for Midwives.* 12th ed. New York, NY: Churchill Livingstone; 1993.

30. Ketter D, Shelton B. In hospital exercises for the postnatal woman. *MCN.* 1983; 8:120-124.

31. Kotarinos RK. *Physical Therapy for Women: Obstetrics Course.* Houston, Tx; Apr 7-8, 1990.

32. Bates B. *A Guide to Physical Examination and History Taking.* 4th ed. Philadelphia, Pa: Lippincott Co; 1987.

33. Gonzales-Ulloa M. Abdominal wall disfigurement. *Annals of Plastic Surg.* 1980;4(5):357-369.

34. Asaadi M, Haramis HT. A simple technique for repair of rectus sheath defects. *Annals of Plastic Surg.* 1994;32(1):107-109.

35. Delitto A, Rose SJ, McKowen JM, et al. Electrical stimulation versus voluntary exercise in strengthening thigh musculature after anterior cruciate ligament surgery. *Phys Ther.* 1988;68(5):660-663.

36. Eriksson E, Haggmark T. Comparison of isometric muscle training and electrical stimulation supplementing isometric muscle training in the recovery after major knee ligament surgery. *Amer Jour Ortho Soc Sports Med.* 1979;7:169-171.

37. Alon G, McCombe SA, Koutsantonis S, et al. Comparison of the effects of electrical stimulation and exercise on abdominal musculature. *JOSPT.* 1987;8(12):567-573.

38. Alon G, Frederickson R, Gallager L, et al. Electrical stimulation of abdominals: the effects of three versus five weekly treatments. *Jour Clin Electrophys*. 1991;4(1):5-11.

39. Alon G, Stookey LA, Lamb JL, et al. The effects of minimal intensity and prolonged electrical stimulation on abdominal strength and endurance. *Phys Ther (Suppl)*. 1994;74:S93. Abstract.

40. Hreka J, Zeubak A, Feriencik K. An attempt to strengthen the abdominal musculature and to reduce the fat layer by means of faradic contractions. *Anthropologia*. 1972;XX:75-79.

41. Iehl CR, Danielson JE, Hoegh JO, et al. Training effects of functional electrical stimulation on abdominal muscles. *Phys Ther (Suppl)*. 1984;64:S751. Abstract.

42. Aikman HD, Majerus JJ, VanWart KW, et al. Effects of electrical stimulation versus situps on abdominal strength and endurance. *Phys Ther (Suppl)*. 1985;65:696. Abstract.

43. Thorek M. *Plastic Surgery of the Breast and Abdominal Wall.* Springfield: Chas C Thomas Books; 1942.

44. Gardner WD, Osburn WA. *Structure of the Human Body*. 2nd ed. Philadelphia, Pa: WB Saunders; 1973.

45. Kotarinos RK. Diastasis recti and review of the abdominal wall. *Jour OB/GYN Phys Ther.* 1990;14(4):8-10.

46. Mantle MJ, Greenwood RM, Currey HLF. Backache in pregnancy. *Rheum & Rehab*. 1977;16:95-101.

47. Fast A, Shapiro D, Ducommun EJ, et al. Low back pain in pregnancy. *Spine.* 1987;12:368-371.

48. Berg G, Hammar M, Moller-Nielsen J, et al. Low back pain during pregnancy. *Obstet & Gyn*. 1988;71:71-75.

49. Goldspink G. Sarcomere length during post-natal growth of mammalian muscle fibres. *Jour Cell Sci.* 1968;3:539-548.

50. Gossman MR, Sahrmann SA, Rose SJ. Review of length-associated changes in muscle. *Phys Ther.* 1982;62(12):1799-1807.

51. Booth D, Chennells M, Jones D, et al. Assessment of abdominal muscle exercises in nonpregnant, pregnant, and post partum subjects using EMG. *Austr Jour Physiother.* 1980;26(5):177-1079.

52. Hatami T. Electromyographic studies of the influence of pregnancy on activity of the abdominal wall muscles. *Tohoku Jour Exper Med.* 1961;75:81-88.

53. Partridge MJ, Walters BS, Walters CE. Participation of the abdominal muscles in various movements of the trunk in man. An EMG study. *Phys Ther.* 1959;39(12):791-800.

54. Godfrey K, Kindig LE, Windell EJ. Electromyographic study of muscle activity in sit-up variations. *Arch Phys Med Rehab.* 1977;58:132-135.

55. Thorton SL, Thorton SJ. Management of gross divarication of the recti abdominis in pregnancy and labour. *Physiother* 1993;79(7):457-458.

56. Massey GB. *Conservative Gynecology and Electro-therapeutics.* Philadelphia, Pa: FA Davis Co; 1902.

57. Domholdt E. *Physical Therapy Research Principles and Applications.* Philadelphia, Pa: WB Saunders, 1993.

58. Portney LG, Watkins MP. *Foundations of Clinical Research Applications to Practice.* Norwalk, Ct: Appleton & Lange; 1993.

59. Wolery M, Harris SR. Interpreting results of single-subject research designs. *Phys Ther.* 1982;62:445-452.

60. Oestreich AE. Ultrasound imaging of musculoskeletal and superficial tissues in infants and children. *Applied Radiology.* 1984;13:83-88.

61. Chhem RK, Beauregard G, Schmutz GR, et al. Ultrasonography of the ankle and the hind foot. *Canadian Assoc of Radio Journal.* 1993;44:337-341.

62. Ikai M, Fukunaga T. A study on training effect on strength per unit cross-sectional area of muscle by means of ultrasonic measurements. *Int Z. angew, Physiol.* 1970;28:173-180.

63. Weiss LW, Clark FC. Ultrasonic protocols for separately measuring subcutaneous fat and skeletal muscle thickness in the calf region. *Phy Ther.* 1985;65(4)L477-481.

64. Sipila S, Suominen H. Muscle ultrasonography and computed tomography in elderly trained and untrained women. *Muscle & Nerve.* 1993;4:294-300.

65. Heckmatt JZ, Pier N, Dubowitz V. Measurement of quadriceps muscle thickness and subcutaneous tissue thickness in normal children by real-time ultrasound imaging. *Jour Clin Ultrasound.* 1988;16:171-176.

66. Heckmatt JZ, Pier N, Dubowitz V. Assessment of quadriceps femoris muscle atrophy and hypertrophy in neuromuscular disease in children. *Jour Clin Ultrasound.* 1988;16:177-181.

67. Torstensen TA, Meen HD, Stiris M. The effect of medical exercise therapy on a patient with chronic supraspinatus tendinitis. Diagnostic ultrasound-tissue regeneration: a case study. *JOSPT.* 1994;20:319-327.

68. Sackett DL. Bias in analystic research. *J. Chronic Dis.* 1979;32:51-63.

APPENDIX A

SUBJECT QUESTIONNAIRE

Group # **Subject #** **Age:**

Total weight gain of last pregnancy: **Race:**

Weight after pregnancy: **Present weight:**

Number of pregnancies: **Present height:**

Number of deliveries: **Method of birth control:**

Currently breastfeeding: Y N **Delivery date:**

Birth weight of last baby:

 # Low back pain rating during pregnancy 0 1 2 3 4 5 6 7 8 9 10
0 = no pain 10 = severe, debilitating pain # excluding labor pain

DIASTASIS RECTI MEASUREMENTS AT 3 SITES:

	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7
Above	______	______	______	______	______	______	______
Umbilicus	______	______	______	______	______	______	______
Below	______	______	______	______	______	______	______
Retest (A U B)	______	______	______	______	______	______	______

	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14
Above	______	______	______	______	______	______	______
Umbilicus	______	______	______	______	______	______	______
Below	______	______	______	______	______	______	______
Retest (A U B)	______	______	______	______	______	______	______

	Week 15	Week 16	Week 17	Week 18	Week 19	Week 20
Above	______	______	______	______	______	______
Umbilicus	______	______	______	______	______	______
Below	______	______	______	______	______	______
Retest (A U B)	______	______	______	______	______	______

APPENDIX B

UNIVERSITY OF OKLAHOMA HEALTH SCIENCES CENTER
72nd Medical Group, Tinker Air Force Base SGO #95-110

Individual's Consent for Participation in a Research Project

I, ______________________________, voluntarily agree to participate in this study entitled "DIASTASIS RECTI: The use of diagnostic ultrasound to objectively measure treatment outcomes following exercise alone and exercise combined with electrical stimulation. A single subject design." This study will be conducted by Mark Anderson, PhD, PT, ATC and Major Kerry Sitler, PT and sponsored by the Department of Physical Therapy.

1. Purpose: I understand that the purpose of this study is to determine the effectiveness of exercise alone or exercise combined with electrical stimulation in reducing a diastasis recti abdominis (a mild separation of two stomach muscles following my vaginal delivery). I further understand that the purpose of this study is to find a more reliable and objective means of measuring a diastasis recti. In this study, diagnostic ultrasound will be used for this purpose. I am being referred by my physician to Physical Therapy because I have a separation in the middle of my stomach following the delivery of my baby.

2. Status of the Devices and/or Procedures: Diagnostic ultrasound is safe and commonly used during pregnancy. After delivery, the ultrasound will be used to image the midline separation between the two rectus abdominis muscles. In addition, the use of exercise and electrical stimulation are common methods of treatment used in physical therapy for muscle re-education. Lastly, I understand that all equipment will be inspected and certified safe prior to the start of this study.

3. Description of Study: I understand that if I agree to participate in this study, I will be asked questions about my weight during and after delivery, asked questions about my low back pain level throughout my pregnancy, and my present weight and height will be taken. Next, I will be positioned in a lying down position and a diagnostic ultrasound will be performed over the midline of my stomach to determine the exact location of the midline separation (diastasis recti.)

Once the exact location of the midline separation is found, I will be randomly placed in either a group that will perform gentle stomach strengthening exercises or a group that receives both exercise and electrical stimulation to help rehabilitate my weakened stomach muscles. I further understand that I will be measured with the diagnostic ultrasound once a week in both the baseline and treatment phases. After starting the treatment phase, the ultrasound measurements will be performed immediately following the third treatment session each week. While in the baseline phase, the ultrasound measurements will be performed each week at my convenience.

I will be monitored three times a week by the co-investigator for compliance with the exercises and/or electrical stimulation protocols once I start the treatment phase. I also understand that the duration of the treatment phase will last four to six weeks.

4. Costs: I understand that I will not receive any charges or bills for participating in this study.

5. Risks: I understand that there is a potential risk for muscle soreness to occur following exercising or from the use of electrical stimulation. In addition, redness or even a rash may occur under the electrodes following the electrical stimulation treatment. If I have any of these side effects, I should report them immediately to the co-investigator. If these side effects become severe, I understand that I may be removed from this study.

6. Benefits: I understand that participation in this study may result in a reduction of the midline separation in my stomach region.

7. Subject Assurances: I understand that my participation in this study is strictly voluntary. No one has coerced or intimidated me into participating in this study. I have not given up any of my legal rights or released any individual or institution from liability for negligence.

I understand that I may withdraw from this study at any time without penalty or loss of benefits to which I am otherwise entitled. I also understand that records of this study will be kept confidential, and that I will not be identified by name in any report or publication. Records of my participation in this study may only be disclosed in accordance with federal law, including the Federal Privacy Act, 5 U.S.C. 552a, and its implementing regulations. DD Form 2005, Privacy Act Statement--Health Care Records, contains the Privacy Act Statement for the records. I understand that records of this study may be inspected by the US Food and Drug Administration (FDA).

I understand that my entitlements to medical and dental care and/or compensation in the event of injury are governed by federal laws and regulations, and if I desire further information, I may contact the 72nd Medical Group Patient Advocacy Representative at (405) 734-8439.

I further understand that if I have questions about this study, or need to report any adverse effects from the research procedures, I will contact Dr. Mark Anderson at (405) 271-2131 or Major Kerry Sitler at (405) 737-1770. Lastly, if I have any questions about my rights as a research subject, I may contact the Director of Research Administration, in the Oklahoma University Health Sciences Center, at (405) 271-2090.

8. Medical Misadventure: I understand that any clinical or medical misadventure will immediately be brought to my attention or, if I am not competent at the time to understand the nature of the misadventure, such information will then be brought to the attention of my guardian or next of kin.

9. Voluntary Participation: I am participating in this study because I want to. Major Sitler has adequately answered any and all questions I have about this study, my participation, and the procedures involved. I understand that Major Sitler will be available to answer any questions concerning procedures throughout this study. I understand that if significant new findings develop during the course of this study which may relate to my decision to continue participation, I will be informed. I have read this informed consent document. I agree to participate in the research freely and voluntarily under the conditions described in this document and understand that I will receive a copy of this signed consent form.

Signature of Research subject and SSN — Date

Signature of Principal Investigator and SSN — Date

Signature of Witness and SSN — Date

APPENDIX C

The University of Oklahoma

Health Sciences Center

DEPARTMENT OF PHYSICAL THERAPY

RECEIVED

JAN 2 2 1995

PERMISSIONS

TO: W.B. Saunders Company
The Curtis Center, Suite 300
Independence Square West
Philadelphia, PA 19106-3399

DATE: January 9, 1995

The University of Oklahoma is preparing to copyright the research masters thesis entitled:
DIASTASIS RECTI: The use of diagnostic ultrasound to objectively measure treatment outcomes following exercise alone and exercise combined with electrical stimulation. A single subject design.

Your permission is requested to reproduce and, if necessary, to redraw or modify the following material for the use in this and all subsequent editions of the work, in English and in all other languages, translations, and other derivative works for distribution throughout the world.

Garner WD, Osburn WA: Structure of the Human Body. 2nd edition. Philadelphia, PA. WB Saunders Co; 1973, page 181. ***The picture diagrams of the anterolateral abdominal muscles will be used to enhance an explanation of these muscles as related to a diastasis recti.***

Full credit to the original source will be given. If you grant permission, please sign this form in the space provided and return it to me. If permission of the author or the artist is needed, kindly provide his/her address. If specific credit to the author or artist is needed, please so indicate.

Thank you.

Permission granted by the copyright owner provided complete credit is given to original source, and provided material to be used has appeared in our publication without credit or acknowledgement to another source.

Arlee Lawley 2/5/95
W.B. Saunders Company Date

Kerry L. Sitler
KERRY L. SITLER, P.T.
305 Remington Ave.
Midwest City, OK 73130

Permission is hereby granted: ______________________________
Signature Date

TEL NO. Jan 25,95 16:07 P.02

The University of Oklahoma

Health Sciences Center

DEPARTMENT OF PHYSICAL THERAPY

TO: Williams & Wilkins
428 E. Preston St.
Baltimore, Maryland 21202

DATE: January 9, 1995

The University of Oklahoma is preparing to copyright the research masters thesis entitled:
DIASTASIS RECTI: The use of diagnostic ultrasound to objectively measure treatment outcomes following exercise alone and exercise combined with electrical stimulation. A single subject design.

Your permission is requested to reproduce and, if necessary, to redraw or modify the following material for use in this and all subsequent editions of the work, in English and in all other languages, translations, and other derivative works for distribution throughout the world.

Kendall FP, McCreary EK, Provance PG: Muscles Testing and Function with Posture and Pain. 4th edition. Baltimore, MD; 1993, pages 147-149, 151. ***The cross sections of the Rectus Abdominis and its sheath diagram will be used to clarify the aponeurosis of the anterolateral abdominal muscles. The origin, insertion, fiber direction and muscle action of the four anterolateral abdominal muscles will be placed in a table format to review their function.***

Full credit to the original source will be given. If you grant permission, please sign this form in the space provided and return it to me. If permission of the author or the artist is needed, kindly provide his/her address. If specific credit to the author or artist is needed, please so indicate.

WAVERLY
Williams & Wilkins • Lea & Febiger • Harwal

Permission granted by the copyright owner, contingent upon terms of the "CONDITIONS OF AGREEMENT" dated 1-26-95.

Per: Veda Rich (Veda Rich)
Date: 1-26-95

Kerry L. Sitler
KERRY L. SITLER
305 Remington Ave.
Midwest City, OK 73130

Signature **Date**

Request received by author on 1/25/95. Response sent by fax to Williams & Wilkins same date.
I hereby give permission for use of material as requested above. Florence P. Kendall Jan 25, 1995

College of Allied Health • Post Office Box 26901 • 801 Northeast 13th Street, Room 235 • Oklahoma City, Oklahoma 73190 • (405) 271-2131

CONDITIONS OF AGREEMENT

The conditions of this agreement are listed below. Please sign and date this form and return with payment (if applicable, see above) to **VEDA RICH**, Permissions Coordinator, Waverly, 428 E. Preston Street, Baltimore, MD 21202-3993, (410 528-4050).

1) This permission will not be valid until a signed copy of this invoice/agreement are received.
2) A credit line will be prominently placed and include: for books - the author(s), title of book, edition, copyright holder - **Williams & Wilkins**, year of publication; for journals - author(s), title of article, title of journal, volume number, issue number and inclusive pages.
3) The requestor guarantees to reprint the material exactly as originally published. Obvious typographical errors may be corrected, typography may be altered to conform with the proposed publication, and changes may be made as necessary in faithful translation. No deletions, alterations, or other changes may be made without the written consent of the copyright owner and author.
4) Rights granted herein are limited to the proposed publication, to reprints, foreign language editions, and worldwide distribution thereof. Rights herein do not apply to revised editions or any versions via electronic media.
5) Rights granted herein are not exclusive and Waverly reserves the right to grant the same permission to others.
6) Waverly can not supply the requestor with original artwork or printed pages.
7) The requestor agrees to secure written permission from the author.

Permission is granted upon receipt of this signed agreement with payment (if applicable) by Waverly. Please retain a copy for your files.

Requestor accepts: Kerry L. Sitler Date: 1-31-95

(Permission valid only if original copyrighted material of a Waverly imprint (Williams & Wilkins, Lea & Febiger, Urban & Schwarzenberg - English Language, and Harwal.)